REPORT RESUMES

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ELECTRONIC TECHNOLOGY, A SUGGESTED 2-YEAR POST HIGH SCHOOL CURRICULUM.

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THE PURPOSE OF THIS REVISED CURRICULUM GUIDE IS TO AID ADMINISTRATORS, SUPERVISORS, AND TEACHERS TO PLAN, DEVELOP, AND EVALUATE PROGRAMS. THE BASIC MATERIALS WERE PREPARED BY THE TECHNICAL INSTITUTE DIVISION OF THE OKLAHOMA STATE UNIVERSITY PURSUANT TO A U.S. OFFICE OF EDUCATION (USOE) CONTRACT. THE FINAL DRAFT WAS PREPARED BY USOE PERSONNEL. TECHNICAL ACCURACY WAS CHECKED BY NINE ENGINEERS, INDUSTRIALISTS, AND EDUCATORS. THE CONTENTS INCLUDE SUGGESTED COURSE OUTLINES, SEQUENCE OF TECHNICAL EDUCATION PROCEDURE, LABORATORY LAYOUTS, LISTS OF LABORATORY EQUIPMENT AND COSTS, SUGGESTED TEXTS AND REFERENCES, A DISCUSSION OF LIBRARY FACILITIES, AND A SELECTED LIST OF SCIENTIFIC AND TECHNICAL SOCIETIES. THE COURSE OUTLINES INCLUDE HOURS REQUIRED, COURSE DESCRIPTION, MAJOR DIVISIONS (OUTLINE), TEXTS AND REFERENCES, AND VISUAL AIDS. THE APPENDIX ALSO CONTAINS EXAMPLES OF INSTRUCTIONAL MATERIALS AND REPORT WRITING STANDARDS. INSTRUCTORS SHOULD BE TECHNICALLY PROFICIENT AND HAVE INDUSTRIAL EXPERIENCE. STUDENTS SHOULD HAVE ONE YEAR OF HIGH SCHOOL ALGEBRA, GEOMETRY, AND PHYSICS AS A PREREQUISITE. THIS DOCUMENT IS AVAILABLE AS GPO NUMBER FS 5.280--80009A FOR $1.00 FROM SUPERINTENDENT OF DOCUMENTS, U.S. GOVERNMENT PRINTING OFFICE, WASHINGTON, D.C. 20402. (EM)

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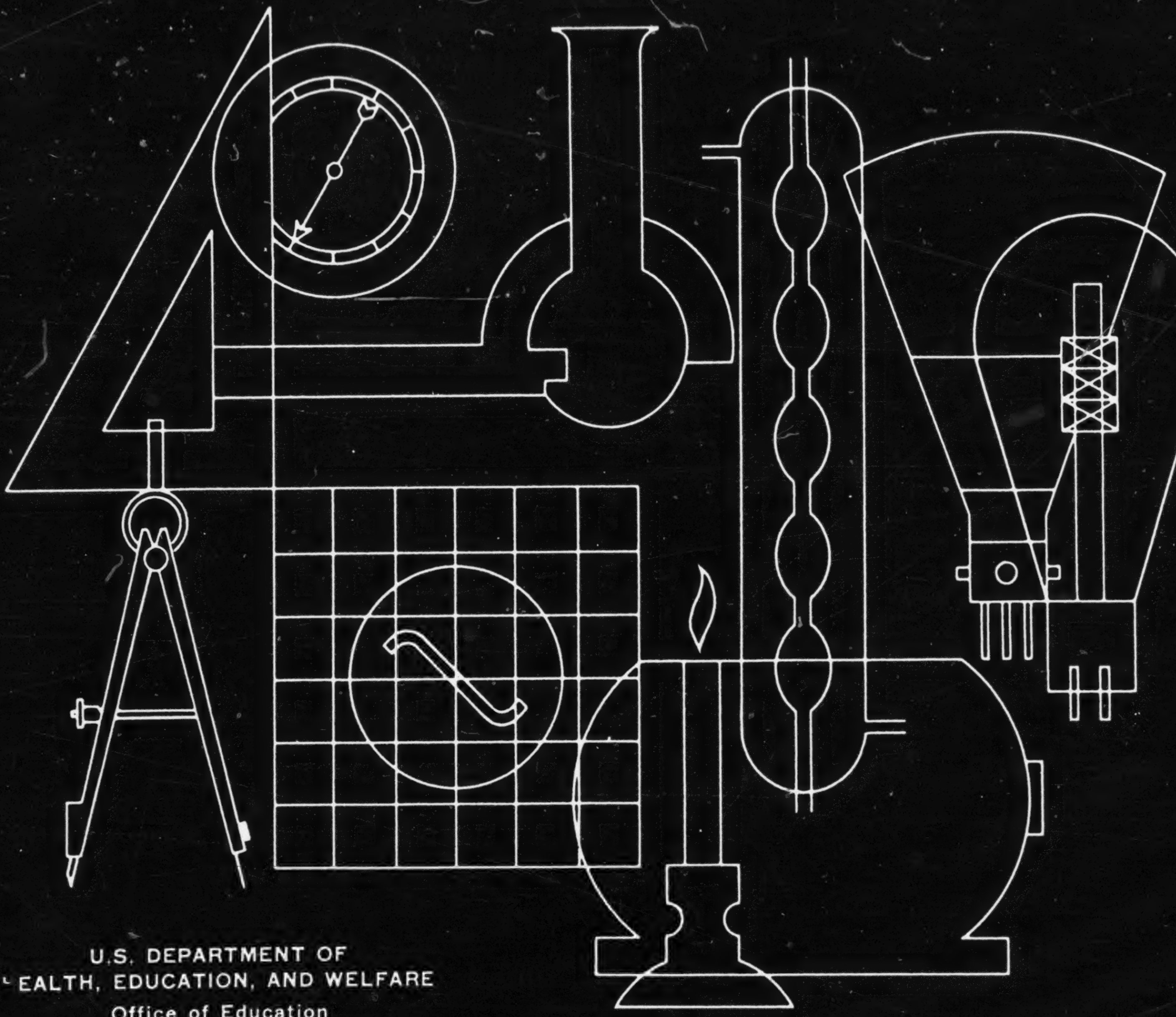
Electronic Technology

A Suggested 2-Year Post High School Curriculum



U.S. DEPARTMENT OF
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OE-80009A

Technical Education Program Series No. 2A . . .

ELECTRONIC TECHNOLOGY

A Suggested 2-Year Post High School Curriculum

U.S. DEPARTMENT OF
HEALTH, EDUCATION, AND WELFARE . . . . JOHN W. GARDNER, *Secretary*
Office of Education . . . . HAROLD HOWE II, *Commissioner*

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FOREWORD

THE ORIGINAL version of this suggested curriculum for a 2-year full-time program to educate highly skilled electronic technicians was published by the U.S. Office of Education in 1960. Rapid technological development in electronics has produced major changes in materials, hardware, and applications since 1960. This publication is a complete revision of the original, designed to retain the essential fundamentals of the first version, to bring it up-to-date, and to modify the suggested curriculum to incorporate the changes in electronic technology which have occurred during the past five years. The need for highly skilled electronic technicians continues to be critical in light of the increasing degree of sophistication in the use of electronics in space exploration, communications, automation of process and systems control, and in many other ways.

The guide offers suggested course outlines, sequence of technical education procedure, laboratory layouts, lists of laboratory equipment and cost, suggested texts and references, a discussion of library facilities, and a selected list of scientific and technical societies concerned with electrical and electronic technology. It is designed to assist school administrators, supervisors, department heads, instructors, and advisory committees who will be planning and developing new programs or evaluating existing programs in electronic technology. Although the indicated level of instruction is post high school, the sequence of course work may well start at any grade level where students have the prerequisite background and understanding.

This revised curriculum guide was prepared by the Technical Education Unit in the Occupations Section, State Vocational Services Branch of the Division of Vocational and Technical Education, U.S. Office of Education. The basic materials for this revision were provided by the Technical Institute Division of the Oklahoma State University pursuant to a contract with the Office of Education. The final draft was prepared under the direction of John A. Beaumont, Director, Occupations Section, by Walter J. Brooking, assisted by Alexander C. Ducat and Robert M. Knoebel.

Many useful suggestions were received from special consultants and from administrators and teachers in schools of technology. Although all suggestions could not be incorporated, each was considered carefully in the light of the publication's intended use. In view of this, it should not be inferred that the curriculum is completely endorsed by any one institution, agency, or person.

The technical accuracy of the curriculum materials is due largely to the work of a group of nine outstanding engineers, industrialists, and educators who thoroughly reviewed these materials in conference with the technical specialists of the Occupations Section.

Walter M. Arnold
Assistant Commissioner for
Vocational and Technical Education

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The Office of Education also acknowledges with appreciation the constructive criticism by administrators and staff members of the following institutions:

Chattanooga State Technical Institute
Chattanooga, Tennessee

Del Mar Technical Institute
Corpus Christi, Texas

DeVry Technical Institute
Chicago, Illinois

Eugene Technical-Vocational School
Eugene, Oregon

Electronics Industries Association
Washington, D.C.

Florida State Department of Education
Tallahassee, Florida

Old Dominion College
Norfolk, Virginia

Oregon Technical Institute
Klamath Falls, Oregon

Philco Corporation
Washington, D.C.

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North Dakota State School of Science
Wahpeton, North Dakota

Norwalk State Technical Institute
Norwalk, Connecticut

University of Houston
Houston, Texas

University of Illinois
Urbana, Illinois

Voorhees Technical Institute
New York, New York

Wentworth Institute
Boston, Massachusetts

Wisconsin State Department of Education
Madison, Wisconsin

CONTENTS

FOREWORD ---------- iii

ACKNOWLEDGEMENTS ---------- v

THE ELECTRONIC TECHNOLOGY PROGRAM ---------- 1

GENERAL CONSIDERATIONS ---------- 3
- Faculty ---------- 5
- Student Selection and Services ---------- 6
- Textbooks, References, and Visual Aids ---------- 8
- Laboratory Equipment and Facilities ---------- 8
- Library ---------- 9
- Scientific and Technical Societies ---------- 10
- Advisory Committees and Services ---------- 11

THE CURRICULUM ---------- 13
- Curriculum Outline ---------- 13
- Brief Description of Courses ---------- 14
- Curriculum Content and Relationships ---------- 16
- Suggested Continuing Study ---------- 20

COURSE OUTLINES ---------- 22
- Technical Courses ---------- 22
  - Electronic Devices ---------- 22
  - Electronic Amplifiers ---------- 25
  - Instruments and Measurements ---------- 28
  - Communication Circuits ---------- 31
  - Introduction to Computers ---------- 34
  - Control Circuits and Systems ---------- 37
  - Communication Systems ---------- 39
  - Electronic Design and Fabrication ---------- 42
  - Introduction to New Electronic Devices ---------- 44
- Mathematics and Science Courses ---------- 47
  - Technical Mathematics I (Algebra and Trigonometry) ---------- 47
  - Technical Mathematics II (Applied Calculus) ---------- 51
  - Physics for Electronics I (Electricity) ---------- 53
  - Physics for Electronics II (Mechanics and Heat) ---------- 55

Auxiliary and Supporting Technical Courses 58
  Circuit Analysis—AC and DC 58
  Technical Reporting 61
  Drawing, Sketching, and Diagramming 63
General Courses 66
  Communication Skills 66
  General and Industrial Economics 69
  Industrial Organizations and Institutions 72

FACILITIES, EQUIPMENT, AND COSTS 74
  General Planning of Facilities 74
  Office Space for Staff 77
  Equipping the Laboratories, and Their Cost 77
  Summary of Costs 85

BIBLIOGRAPHY 87

APPENDIXES 93
  A. Selected List of Scientific or Technical Societies and Associations Concerned with Electrical and Electronic Engineering and its Applications 95
  B. Sample Instructional Materials 98
  C. Suggested Standards for Laboratory Report Writing 103

THE ELECTRONIC TECHNOLOGY PROGRAM

NUCLEAR POWER, radio, radar, sonar, television, computers, automation, manned and unmanned space exploration, communication by telstar, and many other modern accomplishments would be virtually impossible without a highly developed science of electronics. This science has provided man with an array of investigative tools, labor saving devices, precision measuring apparatus, and mass data processing and communication capability considered fantastic and improbable a few years ago. Meanwhile, science promises that future developments using applied electronics will be even more dramatic than the developments witnessed during the past three decades.

Although most of the principles of electricity and electronics have been known for many years, rapid developments in the field have occurred in relatively recent years. The pressure of World War II created an emphasis on applied electronics which caused significant advances and development of many new systems of complex electronic equipment. This effort has been sustained by the preparedness programs of post-war years, the research in space exploration, the demands of the consumer market for more and better labor saving devices, and the need for increased scientific and technical capability.

The application of both old and newly discovered knowledge has caused swift and radical changes in electronic devices and applications. Vacuum tubes were an essential device in the development of radios, talking pictures, television, computers, and many other electronic units or systems. Application of the principles and functions of these systems to space exploration, ballistic missiles and artillery shell proximity fuses, and other systems or devices requiring minimum weight and volume, maximum resistance to shock, and greater precision led to the discovery and development of transistors, diodes, triodes, and printed circuits. These new devices are rapidly superseding the vacuum tube and other related units of a few years ago. Solid state electronic devices, many of them in microminiaturized systems, now comprise over 20 percent of the products of the electronic industry.

The electronic technician must not only have a knowledge of vacuum tubes and understand their use but he also must know about the solid state devices which are superseding them. The solid state devices, whether in microminiaturized systems or not, make the repair or maintenance process one of removing and replacing a part or unit. Special techniques using sophisticated measuring devices and precise diagnostic methods of identifying partial or complete failure of elements in solid state miniaturized units or systems must be learned by the electronic technician. The design of electronic devices into systems, called "packaging," becomes a part of the study of the technician as he assembles electronic systems and analyzes circuits, devices, and units in his class and laboratory work.

The process of educating highly qualified electronic personnel is further complicated by the fact that both the traditional aspects and the radically new technology of electronics based on solid state devices must be mastered in the same amount of time as that previously devoted to learning traditional electronics alone. This time requirement dictates a curriculum that must be highly efficient. Teaching methods must be streamlined in order to convey maximum information to students in a minimum amount of

Figure 1.—Women are finding careers in technology interesting and rewarding.

time and to improve their skills and competencies. Laboratory courses must be well-planned, implemented, and coordinated with classroom work so that each laboratory experience yields maximum understanding and improves the skills of the student.

Courses in the curriculum can no longer be taught as isolated units, but must be carefully integrated into a smoothly progressing curriculum, organized and taught by a closely knit staff to insure proper timing of specific subject coverage.

GENERAL CONSIDERATIONS

The objective of the total curriculum recommended in this guide is to produce a competent electronic technician. The technician must be capable of working and communicating directly with engineers, scientists, and production personnel in his specialized work; of satisfactorily performing work for his employer, and of growing into positions of increasing responsibility. In addition, the graduate technician should be an active, well-informed member of society.

A curriculum which, when mastered, will produce the type of graduate described above, must be carefully designed. Each course must be planned to develop the student's knowledge and skills in that particular area and must be directly integrated into the curriculum. Each course contributes uniquely in the sequence of courses which is specially planned to progress toward the final objective of producing a competent technician. If a close correlation between the courses in the curriculum is not maintained, the curriculum will not provide the depth of understanding required of modern electronic technicians.

The technical content of the curriculum is intended to supply a wide background in the diverse areas of applied electronics. A firm foundation in electricity and basic electronics is planned in the first year. The second year of work builds directly on this background but introduces material from many subject areas, such as communications, wave shaping, computers, microwave, and control systems. The methods of analysis steadily become more sophisticated as the student progresses through the curriculum. There must be a strong emphasis on solid state devices and their related aspects, but the study of vacuum tubes can not be eliminated.

Graduates of this curriculum can expect to find employment in many areas of the electronics field. Each area may require somewhat different abilities and different specialized knowledge and skills for a successful career. Most of these differences will be learned by continued study on the job or in part-time study to master the specifics of a special field. The following listing shows some of the major areas or clusters of job opportunities for electronic technicians, as described by employers:

(1) Research and Development Technician: The technician working directly with engineers and scientists in developing new devices or doing basic research.

(2) Sales and Service Technician: A technician representing a company and its products to a customer. He advises the customer and is capable of installing, operating, trouble shooting, and training the customer's personnel to service and maintain equipment located at the customer's installation.

(3) Operations Technician: The technician working in a manufacturing facility that maintains automated equipment; checking and calibrating measuring equipment; fabricating special electronic apparatus for use in the manufacturing plant; checking and troubleshooting electronic control devices and systems; and training skilled plant workers in the operation of electronically controlled equipment.

(4) Communications Technician: A technician working in broadcast and television installations, microwave networks, or mobile two-way communication systems.

In addition to these four major areas of employment for graduate electronic technicians, there are numerous other areas in which they may work. To list all areas would be impossible, but a few examples may further indicate the wide diversity of employment opportunities available to electronic graduates. Some additional areas are:

(1) nuclear instrumentation technician

(2) electronic component or unit design (packaging) technician

(3) product evaluation technician

(4) quality control technician

(5) biomedical electronics technician

(6) rocket and space telemetering technician

(7) Oceanographic and marine research technician.

Highly skilled technicians must be capable of working closely with engineers and scientists and of supervising and coordinating the efforts of skilled craftsmen and electronic maintenance men. These capabilities allow technicians to be effective members of the scientific team whose work is to plan, assemble, install, calibrate, evaluate, and operate electronic devices and principles as they apply to processes or systems.

Because electronic technicians are employed in varied, numerous, and often specialized situations, the adequately trained electronic technician must have attained certain abilities, scientific knowledge, and technical skills. These have been broadly defined as follows:[1]

1. Facility with mathematics; ability to use algebra and trigonometry as tools in the development of ideas that make use of scientific and engineering principles; and an understanding of, though not necessarily facility with, higher mathematics through analytical geometry, calculus, and differential equations, according to the requirements of the technology.
2. Proficiency in the application of physical science principles, including the basic concepts and laws of physics and chemistry that are pertinent to the individual's field of technology.
3. An understanding of the materials and processes commonly used in the technology.
4. An extensive knowledge of a field of specialization, with an understanding of the engineering and scientific activities that distinguish the technology of the field. The degree of competency and the depth of understanding should be sufficient to enable the individual to do such work as detail design, using established design procedures.
5. Communication skills that include the ability to interpret, analyze, and transmit facts and ideas graphically, orally, and in writing.

The electronic technician will use the foregoing abilities, knowledge, and skills as he performs several (but usually not all) of the following general activities:[2]

1. Applies knowledge of science and mathematics extensively in rendering direct technical assistance to scientists or engineers engaged in scientific research and experimentation.
2. Designs, develops, or plans modifications of new products and processes under the supervision of engineering personnel in applied engineering research, design, and development.
3. Plans and inspects the installation of complex equipment and control systems.
4. Advises and recommends procedures or programs for the maintenance and repair of complex equipment used in extensive control systems.
5. Plans production as a member of the management unit responsible for efficient use of manpower, materials, and machines in mass production.
6. Advises, plans, and estimates costs as a field representative of a manufacturer or distributor of technical equipment and/or products.
7. Assumes responsibility for performance or environmental tests of mechanical, hydraulic, pneumatic, electrical, or electronic components of systems and for the preparation of appropriate technical reports covering the tests.
8. Prepares or interprets engineering drawings and sketches.
9. Selects, compiles, and uses technical information from references such as engineering standards, handbooks, and technical digests of research findings.
10. Analyzes and interprets information obtained from precision measuring and recording instruments and makes evaluations upon which technical decisions are based.
11. Analyzes and diagnoses technical problems that involve independent decisions.
12. Deals with a variety of technical problems involving many factors and variables which require an understanding of several technical fields.

A 2-year curriculum must concentrate on primary or fundamental needs if it is to prepare individuals for responsible technical positions in modern industry. It must be honestly pragmatic in its approach and must involve a high order of specialization. *The curriculum suggested in this bulletin has been designed to provide maximum technical instruction in the time that is scheduled.*

To those who are not familiar with this type of educational service (or with the goals and interests of students who elect it) the technical program often appears to be inordinately rigid and restrictive. While modifications may be necessary in certain individual institutions, the basic structure and content of this curriculum should be maintained.

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[1] U.S. Department of Health, Education, and Welfare, Office of Education. *Occupational Criteria and Preparatory Curriculum Patterns in Technical Education Programs*, OE-80015. Washington: U.S. Government Printing Office, 1962, p. 5.

[2] *Ibid.*

The specialized technical courses in electronics are laboratory-oriented. They provide application of the scientific principles concurrently being learned in the courses in physics and mathematics. *For this reason, mathematics and science courses must be coordinated carefully with technical courses at all stages of the program.* This coordination is accomplished by scheduling mathematics, science, and technical courses concurrently during the first two terms, a curriculum principle that will be illustrated at several points. General education courses constitute a relatively small part of the total curriculum. It has been found that students who enter a technical program do so because of the depth of specialization that the program provides. Nonetheless, many students who elect this type of program will bring to it a background of general study.

Faculty

The effectiveness of the curriculum depends largely upon the competence and the enthusiasm of the teaching staff. The specialized nature of the curriculum requires that the teachers of electronic subjects have special competencies based on proficiency in technical subject matter and industrial experience. It is important also that all members of the faculty understand the educational philosophy, goals, and unique requirements that characterize this area of education.

To be most effective, members of the faculty responsible for this program must have interests and capabilities which transcend their area of specialization. All of the faculty members should be reasonably well oriented in the requirements for study in electronics science and applications so that they may use electronic field examples or subject matter as supporting material in the teaching of their respective courses. For example, if the communications courses are to be of maximum value, the teacher should be familiar with the communications problems and demands placed on electronic technical personnel. The scientific principles taught in courses in physics, mathematics, and measurements require that the course instructors emphasize and illustrate how the principles are applied in electronic design and application.

Thus, teachers of specialized technical subjects require advanced technical training. In the past, many of such teachers have been recruited from the ranks of the engineering profession. Recent experience has shown that engineering technology graduates who have acquired suitable industrial experience and who have continued their technical education often become excellent teachers in this type of program. Persons with this kind of background are more likely to understand the objectives and unique instructional requirements of technical education; and often bring to the program the enthusiasm and an appreciation of the values of technical education that are essential to the success of the program.

Since the programs for highly skilled technicians must consist of a series of well-integrated courses in order to attain the scope and depth of adequate training, careful consideration must be given to when and at what level a new concept is to be introduced. This may be accomplished through "team teaching" which, used in this sense, means the organization of a technical staff into a coordinated teaching unit. Teaching assignments are made on the basis of the individual member's special training and talents. Concurrent courses are closely coordinated by team members to best utilize the student's time while he progresses to higher levels of understanding.

"Team teaching" can be developed and nourished only by the teaching faculty. A weekly departmental staff meeting to encourage the development of "team teaching" is recommended. At these meetings each instructor should check with instructors of concurrent courses to insure that course coordination is being maintained. This is especially important when new courses or new techniques are involved where, if less than optimum coordination is evident, the important factors can be analyzed by those involved and a solution to the problems found quickly.

In addition to keeping concurrent courses well coordinated, staff meetings should provide time for free exchange of ideas on teaching techniques discovered to be useful, and on recently developed laboratory projects which seem to be particularly successful. Any project which appears especially interesting and beneficial to the student should be analyzed to see if the same principles of presentation can be employed in developing other projects. Special attention should be given to any scientific or technical journal articles that may improve the teaching of a subject area, or which present new information for teaching.

To keep a staff effective, faculty members should be encouraged to participate as active members of professional and technical societies. Membership in such organizations will acquaint them with the newest literature in the field and help them to maintain closer liaison with employers of technicians and leaders in the field by attending meetings addressed by leading specialists. Self-development is increasingly being encouraged by school administrators in the form of released time and financial assistance for instructors to attend technical society meetings and special technical teacher training institutes. Periodic or sabbatical leaves give staff members opportunities to increase and up-date their industrial experience and to pursue advanced studies.

When determining teaching loads for instructors of technical specialty courses, consideration should be given to the number of student contact hours required. Fully effective instructors in this special area of education require much more time to develop courses and laboratory materials than do shop instructors or teachers of general education courses. A contact-hour work load of 15 to 20 hours per week usually constitutes a full teaching load for technical specialty teachers. The rest of their time should be spent in assisting students, and in developing their courses and effective laboratory experiments.

Class size must be considered since individual attention is recognized as a vital teaching element. The maximum size of a lecture class may vary somewhat depending on the material to be covered, the lecture room, and teaching techniques used: but for lecturing using a blackboard, classes of 20 to 30 students usually should be considered optimum. If little or no class discussion follows the lecture, the size of the class may be significantly increased by use of overhead projectors to present carefully prepared portions of the lecture normally written on the blackboards.

Careful planning of laboratory teaching schedules is important. Laboratory sections should not be overloaded with students. Effective teaching cannot be accomplished if there are too many students per work-group or if too many different experiments are conducted simultaneously in the same laboratory. If too many students try to work on a project, most of them will not be able to participate sufficiently in doing the work and will not benefit from the experiment. The optimum group size is usually two students per laboratory setup, although some experiments can be effective for groups of three or even four. If too many experiments are run simultaneously, the laboratory instructor cannot be effective and the laboratory experiments cannot be closely coordinated with the theory lectures.

Technical curriculums are designed to produce supporting personnel who increase the effectiveness of engineering teams. This same principle of supporting personnel may be employed to increase the effectiveness of the teaching staff. Staff assistants may be used in stock control to set out the proper equipment for laboratory classes, to keep equipment operating properly, to fabricate training aids, and to do a limited amount of routine paper grading. These important, but time-consuming activities when performed by assistants allow the teaching staff to devote more time for developing the curriculum, preparing hand-outs to supplement lecture material, and insuring that necessary components and properly functioning equipment will be available when needed. Resourceful use of supporting personnel makes it possible to operate with a small but versatile staff which may be maintained as enrollment varies. By adjusting the number of the supporting personnel to the demands of enrollment a school may, to a degree, avoid having too few instructors when enrollment is high and too many instructors if enrollment is reduced. Most of the supporting personnel can usually be recruited from the student body.

Student Selection and Services

While the effectiveness of a technical education program depends greatly upon the quality of the faculty, the program's ultimate objective is to produce high quality graduates. It is essential, therefore, that the students accepted into the program have certain capabilities. If the incoming student's background is inadequate, instructors will tend to compromise the course work to allow for the inadequacies with the probable result that the program will be inadequate in depth and scope.

Students chosen for this program should have similar backgrounds and capabilities and should exhibit some evidence of maturity and seriousness of purpose; otherwise the program might not achieve its objectives. Wide ranges of ability among students can create an inefficient teaching situation, thereby preventing progression of the program at the necessary rate. The amount of material to be presented and the principles to be mastered require students who not only are well prepared in formal course material, but who also have the ambition, desire, and will to master a difficult program and to develop their capabilities to the limit.

The curriculum is designed for high school graduates who have particular abilities and interests. In general, students entering the program should have completed two years of high school mathematics, including algebra and geometry, and one year of a physical science, preferably physics, or the equivalent.

The ability levels of those who do, and those who do not, meet these general requirements will vary greatly. If a student enters a program without adequate preparation, he usually will fail; if a class, or majority of a class, begins without the requisite preparation, the program cannot produce highly capable technicians, and thus will fail. If applicants for admission do not have the necessary mathematics, science, or language skills, they should expect to take remedial work before entering the technical program. If possible, this remedial work should be offered at the school where the applicant plans to enter a technical program.

Effective guidance and counseling is essential. The student should be aided in selecting educational and occupational objectives consistent with his interests and aptitudes. Whenever possible, institutions offering technical education programs should consider the use of standardized or special tests to assist in student selection, placement, and guidance. A student should be advised to reconsider his educational objectives if it becomes apparent that he is more suited to other programs either by lack of interest shown in the technical program or lack of ability to satisfactorily complete the curriculum.

The new student should become familiar with facilities on the campus as soon as possible. In particular, he should be given a tour of the library and should learn the procedures and rules governing the use of the library. If possible, organized field trips to nearby industries should be arranged early in the program to give new students an opportunity to see electronic technicians on the job. These tours may provide motivation and perhaps point out why certain required subjects are important.

A departmental student organization may be formed to help bring together people with similar interests. The meetings of this organization should provide exercise for the students in arranging their own technical programs. Speakers from industry or the showing of selected films may help to stimulate interest at these meetings. Student organizations may assist with and participate in department activities such as "career days" and "open house" events.

Students should be given information concerning student membership in technical societies and should be encouraged to join such societies. Student chapters of professional societies offer an opportunity for the student to receive material of an excellent quality on a regular basis at nominal costs. After graduation the technician may find membership in professional organizations and regular reading of their journals very helpful in keeping up-to-date in his field.

Students should be encouraged to get the Federal Communications Commission First Class License as quickly as possible since it is a requirement for employment in many areas of industry. Although preparation for this license is not part of the curriculum, most students educated in this type of program should have little difficulty in acquiring the license. As graduation approaches, students should be made aware that technicians may now be certified and that certification may be one of the criteria for employment.[1]

Academic achievement of students should be recognized in some manner. Many institutions grant an associate degree as tangible recognition of achievement upon graduation. One function of a departmental club could be to present an annual award to an outstanding graduate. Industrial organizations might offer to contribute to an annual scholarship award.

Graduates of technical programs should be aided in every way possible in finding suitable employment. Placement personnel should be aware of the needs of industry for electronic technicians and should acquaint prospective employers with the qualifications of graduates. The placement function is an extremely valuable service to the student, the institution, and the employers. In the final analysis, the placement of graduates is an important responsibility, which is, directly, or indirectly, the concern of the department head or the instructor who teaches the technical specialty. An excellent placement record is important in getting new enrollees. In addition, the school should conduct periodic follow-up studies of their graduates to determine their progress and to evaluate their training. Many times this information can indicate how the curriculum or teaching techniques could be improved.

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[1] Information concerning the certification of engineering technicians may be obtained from:

Institute for the Certification of Engineering Technicians
2029 K Street, N.W.
Washington, D.C. 20006

Textbooks, References, and Visual Aids

Textbooks, references, and visual aids for teaching any technology must be reviewed constantly and supplemented in light of (1) the rapid developments of new knowledge in the field, and (2) the results of research in *methods* of teaching and developing basic concepts in the physical sciences and mathematics. This is especially true in the electronics area. The impact of the development of whole new areas of theoretical and applied scientific knowledge is demanding fresh textbooks, references, articles in scientific and technical journals, and visual aid materials.

New textbooks will reflect recent methods of teaching scientific principles and applications as fast as current research in education becomes applicable. Recent extensive research in methods of teaching mathematics, basic electronics, and physics certainly will produce changes in teaching materials and methods. It is, therefore, mandatory that instructors constantly review modern texts, references, and visual aid materials as they become available and *adopt* them when they are an improvement over those suggested here or those presently in use.

The suggested texts and references have been carefully selected. From the lists presented it should be possible to select suitable ones. However, it should not be assumed that unlisted books are not suitable—there are, no doubt, others which are excellent.

Before a department head or instructor undertakes a program in electronics technology, or any course contained in the curriculum, it is urged that he familiarize himself with the texts and references listed here and others which are available. He will then be able to select the text which best serves his particular needs in making a lucid high-level technical presentation to his students.

Visual aids can be of great help in many teaching programs. The aids which are noted have been selected from an extensive list and represent those considered most suitable at the time the curriculum was prepared. Many are not listed because the variety and extent of the materials make an all-inclusive listing prohibitive. From those listed and others available and pertinent, an instructor may select visual aids which meet his teaching objectives. Visual aids should *always* be previewed and studied prior to using them in a teaching situation.

Laboratory Equipment and Facilities

Laboratories and equipment for teaching electronic technology programs must meet high standards of quality since the objectives and the strength of the programs lie in providing valid laboratory experience, basic in nature, broad in variety, and intensive in practical experience. Well-equipped laboratories with sufficient facilities for all students to perform the laboratory work are required for these courses. The training program should include experiences which illustrate the function and application of a wide variety of electronic components, devices, units, and systems.

Variety and quality of equipment and facilities are more important than quantity in equipment laboratories. Laboratory equipment and facilities are a major element of the cost of such a program, but they are indispensable if the training objectives are to be met.

Equipment must be of good quality if laboratory work is to supply valid experiences for the student. Inferior equipment may not show the principles being

Figure 2.—An adequate education program for technicians requires modern equipment comparable to that used in industry.

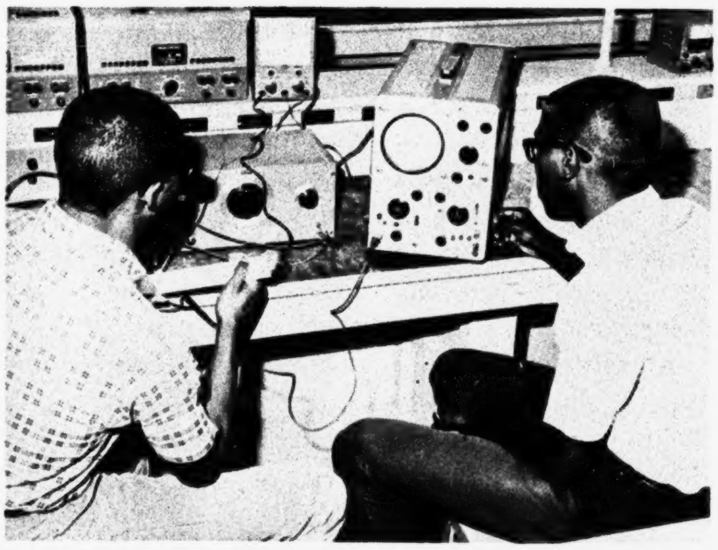


Figure 3.—Students perform experiments using high quality precision equipment. This insures laboratory experiences that reinforce basic laws covered in theory.

studied or may not be sensitive enough to provide reliable or precise data. Such equipment may require unreasonable amounts of time and expense for repairs or adjustment. It is recognized that the initial cost of high quality equipment is usually greater than that of low quality, but the difference in cost is justified because it makes possible laboratory experiments that give precise results.

In the selection of laboratory equipment, the need for each item should be well established. Expensive apparatus may not always be required. Many significant experiments can be built around relatively inexpensive components. In fact, in many cases they can make the principles more evident because they present only the essentials. The number of units purchased, the particular areas of interest, the particular industry emphasis, and the ingenuity of the instructor(s) in adapting equipment to teaching needs will play a major part in governing the selection and cost of laboratory equipment. Throughout the program, the emphasis should be on the principles which serve as the basis for so many different electronic materials, devices, units, and systems.

A recommended approach to developing laboratory work and equipping electronic laboratories is to determine what experiments are needed for each course and then to design these experiments as far as possible using *standard components*. This approach requires more time and effort on the part of the staff, but because the experimental equipment has been assembled to demonstrate some principle or to make a specific experimental determination with clarity and precision, it usually accomplishes the best teaching. The cost is usually less than if similar experiments are taught using more generalized systems of equipment. The standard components may be used for several different experiments during a series of courses by employing the quick connect-disconnect method to assemble them into a system or series without permanent soldered connections, thus saving valuable time and materials. It is good experience for student technicians to make such assemblies as a part of building experimental systems. Laboratory equipment and facilities are dealt with in more detail in a later section entitled "Facilities, Equipment and Costs."

Library

In any evaluation of a technology teaching program a tangible indication of the strength of the program is shown by the following points: the qualifications of the librarian; the library facilities; the quality, quantity, and relevancy of content; and the staffing and organization of the library.

Dynamic developments causing rapid changes in technological science and practice make it imperative that the student of any technology learn to use a library. Therefore, instruction for technology students should be library-oriented so that they learn the importance of being able to find information relative to any of the various courses they are studying and form the habit of using the library as a tool in the learning process. This helps to develop the professional attitude in the student and further assists him to depend on libraries as a means of keeping abreast of the new developments in a rapidly changing technology when he graduates and is employed.

Instructors of all courses should keep the student constantly aware of the extent to which library use is a part of the study in his curriculum. Planned assignments that require the student to use the library to prepare reports on pertinent subjects in his courses will enable him to understand the resources available and their relation to his technology. Open book examinations that require the use of the library provide excellent and objective experiences for the student. Under the incentive of the examination and the pressure of time, an understanding of his own competency in library skills becomes clear to each student.

The growth and success of the graduate technician will depend largely on his ability to keep abreast of changes in his field. Libraries are information source agencies with trained personnel who classify source data and assist those seeking it to find pertinent information quickly.

For these reasons a central library under the direction of a professional librarian is important to the success of the technology curriculum. Most instructors have private libraries in their offices from which they may select books of special interest in their personal conferences with students and thereby stimulate interest in related literature. However, a central library, under the direction of a professional librarian, insures the acquisition and cataloging of the library content according to accepted library practices and provides accessible location of reference materials by the use of systematic card files. It also provides a system for lending books to students in a controlled and orderly manner typical of libraries which they might use later in solving problems as an employed technician.

Study space with suitable lighting and freedom from outside distractions should be provided in the library for study of reference data; and provisions for loaning reference materials for out-of-library use should be systematic and efficient.

The contents of a library must adequately provide the literature encompassed by all subjects in a curriculum and extend somewhat beyond the degree of complexity or depth encountered in classroom activities. Literature dealing with highly specialized aspects of a subject may be acquired as needed or may be borrowed by the librarian from more comprehensive libraries.

The teaching staff and the library staff should actively cooperate concerning what materials are to be acquired, and should be responsible for the final selection of the materials that support their technical courses. They must take the initiative in recommending materials to keep the library content current, pertinent, and useful. The library staff should supply the teaching staff with a periodic list of recent acquisitions complete with call numbers. Technical and trade journals either should be circulated to the teaching staff or be placed in a staff reserve area for a short time before they are made available for general library use.

In addition to reference materials, journals, and trade publications, a library should have encyclopedias available for quick reference and should maintain index material such as the *Engineering Index* to aid staff and students in finding recent material on specific subjects.

Visual aid matters may be centered in the library. Visual aids should be reviewed and evaluated by both the librarian and a member of the teaching staff as they become available. This procedure will inform the teaching staff regarding the visual aids that are available and where they may be used best in the technical programs. Visual aids should *always be previewed* and analyzed for timeliness and pertinency before being used in a teaching situation.

A well-equipped, modern library should have some type of duplicating service available so that copies of library materials may be easily obtained by students and staff. Such a service allows both students and staff to build up-to-date files of current articles appropriate to the courses in a curriculum. The service should be available to the students at a minimum cost and free of personal cost to the teaching staff. A satisfactory arrangement, based on experience, utilizes a large dry copy machine and allows the duplication of library materials for students at the rate of five cents per page. The teaching staff is allowed duplication of up to twenty pages per day without personal charge to the instructor. Any excess is either charged to the department having material duplicated or to the staff member at the rate of five cents per page.

Scientific and Technical Societies

Scientific and technical societies are an important source for instructional materials and other potential opportunities for benefits to both staff and students. Such societies provide, in their publications and in their regularly programmed meetings, a continuing disclosure and discussion of new concepts, processes, techniques, and equipment in the science and related technologies. They are probably the greatest single device by which persons interested in a particular phase of science keep abreast of new developments. Their data are presented in such a manner as to provide a "popularizing" and informative bridge between the creative theoretical scientist and the applied sciences practitioners, including the technicians, and usually are the first medium to announce and describe significant discoveries and applications of research in the field.

Teachers in technical programs should be encouraged to become active members in scientific and technical societies to enable them to keep abreast of new developments in the technology and to become acquainted with people in the community who are most actively interested in the field. Some educational institutions pay all or part of the cost of membership in selected societies, and all or part of the cost of attendance at local or national society meetings as a means of encouraging staff activity in such societies.

Early in their study program students should be made aware of the literature and services of scientific, technical and engineering societies. Student affiliate memberships are offered by some of these societies, and students should be encouraged to become such members.

The Institute of Electrical and Electronics Engineers (IEEE), Box A, Lenox Hill Station, New York, N.Y. 10021, is a technical society which serves the electrical and electronic scientist, engineer, technician, teacher, and student. The Society has a membership in excess of 156,000 (including some 20,000 students); and has 200 local and regional sections many of which have student chapters. Its major publications include *Proceedings of the IEEE*, monthly; *IEEE Spectrum*, monthly; *IEEE Student Journal*, bimonthly; *IEEE Directory*, biennial; and *IEEE Transactions*, irregular.

Some other scientific and technical societies whose publications and services may be of interest to electronic technician teachers and students are:

American Institute of Aeronautics and Astronautics
American Institute of Physics
American Institute of Plant Engineers
American Nuclear Society
American Radio Relay League, Inc.
American Society for Engineering Education
American Society of Safety Engineers, Inc.
American Specification Institute
Armed Forces Communications and Electronics Association
Audio Engineering Society
Conference on Electrical Insulation
Illuminating Engineering Society
Instrument Society of America
National Association of Power Engineers, Inc.
Radio Technical Commission for Aeronautics
Society of Aerospace Material and Process Engineers
Society for Experimental Stress Analysis
Society for Nondestructive Testing, Inc.

A brief description of these societies and their publications as of 1965, is given in Appendix A.

Advisory Committees and Services

Experience has shown that almost all successful technical education programs are assisted by and demonstrate the benefits of the use of advisory committees and special consultants. Most institutions have an advisory committee or committees to assist the administration in planning and implementing overall programs to meet the objectives of the institution and the needs of those whom it serves. In addition, each specific technology program or other specialized occupational objective has a special curriculum advisory committee made up of representatives of employers, civic leaders, public employment services, scientific or technical societies and associations in the field, and the specialists from the staff of the school.

The curriculum advisory committee usually is appointed by the chief administrator or the dean of the institution when it becomes evident a particular technology should be considered as a program to be offered by the institution. The advisory committee then assists in making the necessary survey of the needs for the technicians; what they should be able to bring to an employer to meet the requirements of the employment opportunities; available student population, curriculum, faculty, laboratory facilities and equipment; and cost and financing of the program. Often the committees provide substantial support to school administrators in requesting appropriations, raising public funds, and in obtaining State or federal support for the program.

Sometimes the studies of the curriculum advisory committee show that a proposed program should not be undertaken. When the studies indicate that a program should be initiated, the support and assistance of the committee in planning and initiating the program is invaluable. When the first few classes of students graduate and seek employment, the committee assists in placing them in jobs and helps to evaluate their performance. Minor modifications often are made in the program as a result of these evaluations.

Committee members usually are appointed for a year so that the duties will not become a burden to any individual member and so that other qualified and interested people may have the opportunity to serve. The average committee usually consists of about twelve members, but this number may vary from six to twenty. Those selected to serve are usually busy people and meetings should be called only when there are problems to be solved or tasks that committee action can best accomplish. The head of the institution or department head of the technology usually serves as chairman. Such committees serve without pay as interested citizens. They enjoy no legal status, but provide invaluable assistance whether serving formally or informally. The continuous support of an advisory committee has been found to be a constant source of strength for the program; and the most reliable means of keeping a successful, high quality, and up-to-date program.

As stated in the Foreword, this publication is intended as a guide for program planning and development, primarily in post high school institutions. It is expected that adaptations will need to be made to suit various situations in schools in differing localities. The assistance of an advisory committee and of special consultants, using guides such as this as a starting point and modifying it to meet local needs has been found to be an effective means of initiating needed programs and developing them quickly to a high level of excellence. The courses in guides such as this have often been modified by schools and their advisors to serve the needs of employed adults who need to update or up-grade their skills and technical capability.

THE CURRICULUM

Curriculum Outline

Courses	*Class hours*	*Laboratory hours*	*Outside study*	*Total hours*
First Semester				
Physics for Electronics I (Electricity)	3	6	6	15
Technical Mathematics I (Algebra and Trigonometry)	5	0	10	15
Electronic Devices	3	6	6	15
Communication Skills	3	0	6	9
Total	14	12	28	54
Second Semester				
Physics for Electronics II (Mechanics and Heat)	3	3	6	12
Technical Mathematics II (Applied Calculus)	4	0	8	12
Circuit Analysis—AC and DC	3	6	6	15
Electronic Amplifiers	3	6	6	15
Total	13	15	26	54
Summer Session (Optional)				
Studies to meet special requirements of State or institution				
Third Semester				
Instruments and Measurements	3	6	6	15
Communication Circuits	3	6	6	15
Introduction to Computers	4	3	8	15
Technical Reporting	2	0	4	6
Drawing, Sketching and Diagramming	0	3	0	3
Total	12	18	24	54
Fourth Semester				
Control Circuits and Systems	3	3	6	12
Communication Systems	3	3	6	12
Electronic Design and Fabrication	1	5	0	6
Introduction to New Electronic Devices	2	0	4	6
General and Industrial Economics	3	0	6	9
Industrial Organizations and Institutions	3	0	6	9
Total	15	11	28	54

Brief Description of Courses

First Semester

Physics for Electronics I (Electricity)

A study of current flow and direct current circuits. The course presents work with magnetic circuits and introduces time varying currents. This course utilizes mathematics tools as they are developed in the mathematics course. It is strongly laboratory-oriented to develop knowledge and skills.

Technical Mathematics I (Algebra and Trigonometry)

A course in algebra and trigonometry with particular stress on the solution of systems of linear equations, trigonometry related to the right triangle, and the use of complex number notation. The sequence of subject matter is closely correlated with *Physics for Electronics I* and *Electronic Devices* courses, taught concurrently.

Electronic Devices

A study of electronic devices; how they work, nomenclature, materials, apparatus, and characteristics. Both tube characteristics and solid state device characteristics are covered. This course utilizes the mathematical tools as they become available and the ideas of electron flow and circuit analysis as they are developed in the *Physics for Electronics I* (Electricity) course. Laboratory techniques and skills are taught by extensive use of a variety of devices and equipment.

Communication Skills

A program designed to promote greater competence in reading, writing, talking, and listening.

Second Semester

Physics for Electronics II (Mechanics and Heat)

A study for the basic principles of physics, emphasizing mechanics and heat, with particular emphasis on those principles embodied in the design of electronic devices.

Technical Mathematics II (Applied Calculus)

A course covering the elements of analytic geometry, differentiation, integration and Fourier series. Emphasis is placed on differentiation and integration as applied to technical problems.

Circuit Analysis, AC and DC

A continuation of Physics for Electronics I (Electricity) emphasizing AC circuit theory and both AC and DC network theorems. This course provides the background needed to analyze complex networks with both active and passive elements present.

Electronic Amplifiers

A continuation of Electronic Devices. Many of the devices studied in the first semester are used in forming amplifier circuits. Amplifiers, both transistor and tube types, are covered with emphasis on methods of analysis and design procedures. A student should be capable of limited design of amplifiers to specifications using either tubes or transistors upon completion of this course.

Third Semester

Instruments and Measurements

A course concerned with the accuracy of measurements, how instruments work, proper use of instrument, and calibration techniques. Emphasis is placed on how to use and calibrate general laboratory equipment. Measuring methods and techniques for various frequency ranges are studied.

Communication Circuits

A continuation of the *Electronic Amplifiers* course covering class C power amplifiers, oscillators modulation, small signal tuned amplifiers, and detector circuits. Emphasis is on using transistors in communication circuits and the underlying principles of operation of the various classes of circuits studied.

Introduction to Computers

A course that employs principles from almost all previous technical courses as it familiarizes the student with both analog and digital computers. Emphasis is placed on principles of operation and on circuitry used in these computers. The binary number system and Boolean algebra are covered. Computer use for measurement, comparison logging, data storage and retrieval, and system control is studied.

Technical Reporting

A study of effective ways of presenting information. The student learns the utility of illustrations and outlines for various types of oral and written formal and informal reports. Conciseness, accuracy, and form are emphasized.

Drawing, Sketching, and Diagramming

A course designed to develop illustrative and graphic communication skills, with emphasis on presenting information effectively by using diagrams, drawings, prints, sketches, graphs, and charts drawn freehand and employing commonly available drawing aids such as straight edges, curves, squared or graph paper, and similar aids.

Fourth Semester

Control Circuits and Systems

An investigation of various control circuits, commonly employed in industry. These circuits are then used in systems, and various methods of systems analysis are used to predict the performance of a complete system.

Communication Systems

A continuation of the *Communication Circuits* course covering transmitters, receivers, transmission lines, antennas, and introducing microwave systems. This course emphasizes systems used to transmit information from one point to another using radio frequency techniques.

Electronic Design and Fabrication

A course directed toward teaching proper chassis layout and equipment arrangement (packaging) and toward building a functional electronic unit of some kind. Modern printed circuit layout and fabrication are covered. Throughout the curriculum little emphasis has been placed on construction details—thus bread-board techniques often have been used to save valuable laboratory time throughout the curriculum. The student at this point has a firm foundation in electronics and can undertake the problems of proper design and fabrication of electronic equipment.

Introduction to New Electronic Devices

A study of new electronic devices, materials, techniques, and applications. This is a unique course, since it depends heavily on the judgment of the teaching staff. The subject matter coverage will change rapidly as new developments in industry are announced. It may be noted that a few of the topics appearing in the list for this course are contained elsewhere in the curriculum (such as tunnel diodes and field effect transistors). It is expected that new information will be developed through this course and will find a permanent, appropriate position in the curriculum.

General and Industrial Economics

A study of general economics principles, and an analysis of the factors involved and importance of cost control in an industrial enterprise.

Industrial Organizations and Institutions

A study of roles played by labor and management in the development of American industry. An analysis is made of forces affecting labor supply, employment, and industrial relations under the democratic system of government.

Curriculum Content and Relationships

Functional competence in a broad field such as electronics has at least three components around which a curriculum must be designed:

1. (1) The training should prepare the graduate to be a productive employee in an entry level job.
2. (2) The broad technical training, together with a reasonable amount of experience, should enable the graduate to advance to positions of increasing responsibility.
3. (3) The foundations provided by the training must be broad enough so that the graduate can do further study within his field. This further study may consist of the reading of journals, new text materials, or enrolling in formal courses.

This curriculum has been designed to meet these requirements.

A two-year technology program has certain unique requirements that influence the content and organization of the curriculum. Some of these requirements are imposed by the occupational functions that graduates are expected to perform; some result from the emphasis of industry on particular areas of electronics; some may be incidental to the need or special attention to content that will maximize the effectiveness of teachers who have special competencies; and others result from the limited time available to produce a competent technician in such a diverse field. This electronic technology curriculum guide reflects three basic requirements: functional utility, units of instruction in specialized technical subjects, and provision for the teaching of principles by application.

The sequence of courses in a 2-year technical curriculum is as important as the content of the courses if the limited time available is to be used to full effectiveness. In general, the subject matter in the curriculum is carefully coordinated in groups of concurrent courses which are arranged to blend smoothly from one group of courses into the next, thus carrying the student to a deeper understanding of basic principles while broadening his scope of understanding in the many diverse areas of electronics. This is in sharp contrast to the arrangement of the usual professional curriculum in which basic and somewhat unrelated courses make up the first part of the study program and specialization is deferred to subsequent terms.

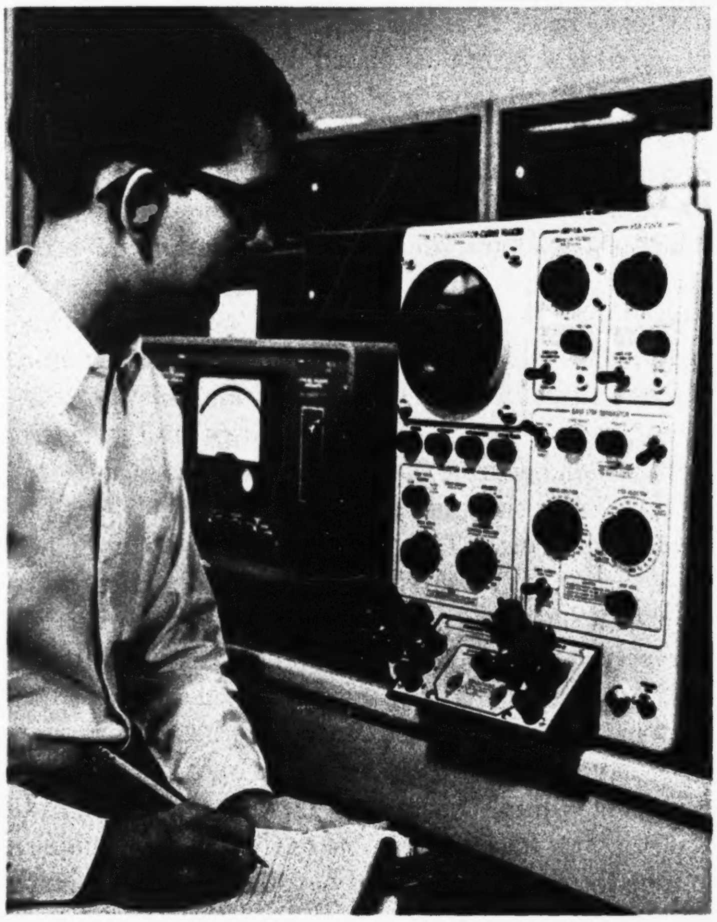
The relationship between laboratory time and class lecture or theoretical study time is of great importance in a technical education curriculum. All of the theory, skills, techniques, applied principles, materials, knowledge, processes, and understandings needed by the technician could be taught in the laboratory without separate and organized theoretical classes. The converse is *not* true—laboratory experience, skills, know-how and capability, which are the most characteristic attributes of technicians, *cannot* be learned in classrooms *without laboratories*. However, organized and related ideas, concepts, and factual information can be taught in "theory" classes, judiciously using demonstrations and visual aids, employing selected texts and references, and requiring regular and systematic outside study on the part of the student. Group teaching usually makes more efficient use of the instructor's time in a "theory" class than in a laboratory and tends to emphasize and develop the student's skills in obtaining knowledge from printed sources. Thus, there must be a special relationship between the amount of the scientific and technical specialty taught in the "theory" classes and that taught in the laboratory.

Figure 4.—Teams of two students each is the optimum arrangement for most electronic laboratory study.

This curriculum provides a large part of the time for laboratory hours in the technical specialty during the first two semesters, because introductory and elementary laboratory skills and knowledge of apparatus, tools, processes, materials, devices, and good practice can (and should) be learned in the laboratory as early as possible and can be started without much underlying theory. As soon as the underlying theory can be developed and understood, it can be incorporated into the laboratory work and becomes a significant experience for increasing the depth of subjects being taught.

Since many basic laboratory skills and enough basic theory have been learned in the first year, the laboratory time required to illustrate principles and to teach new basic material in second year courses need not be as long as in the first year. Since more technical specialty courses are studied in the second year than in the first, the total time spent in the laboratory is greater than that spent during the first year. Experience has shown that the relative number of semester hours of science or technical specialty laboratory work compared to the number of hours of class theory, should not be reduced materially in courses for electronic technicians. Such a reduction usually causes the typical student to lose interest and fail, or to abandon the course. It can also produce a graduate who is deficient in the absolutely essential laboratory capabilities, is untrained for his occupational objective, and is unemployable at the technician level.

Figure 5.—Solid state devices are an important aspect of modern electronics curriculums. Students must learn to use instruments commonly encountered in industry to study these devices.



The laboratory hours suggested in the curriculum outline and in the course descriptions are not necessarily intended to be in a single session, but rather as total hours of laboratory per week to be scheduled in reasonable and effective increments. For example, a 6-hour laboratory total per week or a course might be scheduled as three 2-hour sessions or two 3-hour sessions but seldom, if ever, would be scheduled for longer periods.

In technical curriculums it is mandatory that specialized technical course work be introduced in the first semester. Deferring this introduction even for one term imposes serious limitations on the effectiveness of the total curriculum. Several important advantages occur from an early introduction of the technical specialty:

(1) It provides motivation. Since the student enrolled in school to study electronics it is important to start his training immediately in his specialty. When the first semester consists entirely of general subjects—mathematics, English, general science, and social studies, technical students often lose interest.

(2) It is possible to achieve greater depth of understanding in specialized subjects in the later stages of the 2-year program.

(3) The student sees immediate application of the principles he studies in the mathematics and the *Physics for Electronics I* course.

The technician's work often involves potential dangers that require the use of careful procedures combined with an understanding of equipment and observance of normal safety practices. In addition to protecting human life, careful workmanship will protect delicate apparatus and expensive test equipment. Safety must be a constant preoccupation, and its practice must be emphasized continually from the beginning of the course.

Intellectual honesty must be a part of the training and discipline of any technician. He must report accurately what he observes. Any modification of the observed data should be fully explained in his record of the work. False reporting should be dealt with severely by the instructor. The original data recorded by an employed technician may become evidence in a court of law and are of great importance.

A laboratory notebook should be required for all laboratory courses. Throughout the course of study the student is trained in the scientific method of observation and to record his observations in laboratory reports. During the fourth semester he will

Figure 6.—Mastery of the latest equipment and techniques must be an integral part of a modern electronics curriculum to prepare student technicians for the technological changes of tomorrow.

record his observations in a laboratory log book. A laboratory log book is a bound journal-type notebook with "numbered" pages in which the student is required to make a permanent record of each laboratory experiment including the objective thereof, all pertinent circuit drawings, equipment list, all observed and computed data, date the experiment was performed, and name of the observer. Its use approximates the journal recording required of most employed technicians. The laboratory log is recommended for use during the final semester of the technical curriculum and should constitute a complete chronological record of a student's technical course work throughout the semester.

The course outlines in this guide are short and descriptive. The individual instructor will have to prepare complete courses of study and arrange the curriculum material in logical order before starting instruction. Suggested laboratory layouts and equipment in the Facilities, Equipment and Cost Section will be helpful in organizing the program. As previously mentioned, the subjects of specialization are introduced in the first semester in close correlation with other subject matter.

During the first semester *Physics for Electronics I* (*Electricity*) provides the theory and some of the laboratory techniques which underlie the technical specialty courses in the entire curriculum since electronic considerations are all related to electrical phenomena. The *Electronic Devices* course introduced in the first semester provides intensive laboratory experience in the use of electronic devices, construction, practices, operation, measurement, adjustment, and related laboratory skills. A total of 12 semester hours of laboratory work is provided in these two courses. It is recommended that part of the first four laboratory periods of *Electronic Devices* be used to teach the use of the slide rule to provide students with this tool without delaying the learning of important mathematical principles in *Mathematics I*. The course in *Mathematics I* strengthens the understanding of *Physics for Electronics I* and *Electronic Devices*. For example, as soon as simple equations have been covered in *Technical Mathematics I*, this tool may be used to help analyze simple circuits in *Physics for Electronics I* (*Electricity*). As soon as linear, and non-linear resistances are studied in *Physics for Electronics I* (*Electricity*) and a graphical method of establishing an operating point is developed, the same concept may be applied to load-line analysis in the *Electronic Devices* course. This type of correlation of course content must be continued throughout the first year.

The second semester continues the same type of integrated teaching with *Technical Mathematics II* (*Applied Calculus*) supplying important numerical and quantifying capability in studying *Circuit Analysis AC and DC*, *Electronic Amplifiers*, and *Physics for Electronics II* (*Mechanics and Heat*).

Technical Mathematics II concludes the sequence of selected topics in algebra, trigonometry, analytical geometry, and calculus which comprise the mathematics courses. The inclusion of calculus in *Technical Mathematics* is not intended to make the student proficient in all aspects of calculus but rather to help him understand concepts which will permit him to understand calculus as a basic tool in problem analysis and in communicating with engineers. The student's background in calculus should be broad enough to allow him to follow, though not necessarily reproduce, the development of equations which require the use of calculus. Examples might include the differentiation of elementary functions for determination of instantaneous velocities and accelerations which occur in the study of physics and the use of calculus in the analysis of transient conditions and control systems. The mechanics learned in *Physics for Electronics II* contributes essential understanding of the mechanical principles underlying application of electronic devices to control of devices and important considerations of heat in electrical and electronic systems and units. The 15 hours of laboratory work in the sciences and technical courses provide for practical demonstration and application of the principles being learned or of those learned previously.

The third semester's study is based on the student's accumulated knowledge of physics, mechanics, electricity, circuits and amplifiers, acquired during the first two semesters. New material usually is either a refined restatement or an extension of principles learned previously. Thus, *Instruments and Measurements*, *Communication Circuits*, and *Introduction to Computers* extend and apply in greater depth the concepts of circuitry; sophisticated systems of devices to measure or compute; and precision in measuring, sensing, analyzing, and control. The 18 laboratory hours scheduled for the third semester are necessary in order to provide intensive experience in a great variety of complex devices, systems and units covered in that semester, and to provide comprehensive practical experience. Essential skills developed in *Drawing, Sketching, and Diagramming* enable the student technician to represent data, systems, devices, designs, or concepts. Practice in these skills is emphasized in the concurrent course *Technical Reporting*.

Courses in the fourth semester develop further depth of comprehension and provide practice in the application of principles, techniques, skills, and concepts previously learned. *Control Circuits and Systems* and *Communication Systems* apply knowledge of circuit analysis, transmitter and receiver systems to communication and control networks; they integrate the concept and application of analog and digital computers into such systems as an engineering tool or as a key component of a controlled system.

Figure 7.—Students must receive personal attention from competent staff members to insure that laboratory experience provides effective mastery of skills and proof of theory.

The *Electronic Design and Fabrication* course requires a project which gives the student a chance to work with minimum supervision. It requires the use of concepts, principles, devices, techniques, and laboratory skills in a manner similar to that most often required on the job as a beginning technician. The results of the entire 2-year curriculum may well be reflected in the project for this course.

General and Industrial Economics, and *Industrial Organizations and Institutions*, the social science courses, are designed to broaden the student's concepts of the society in which he lives and will be employed. These courses include broad economic and industrial concepts with sufficient emphasis on corporate structure and economics to enable the student to comprehend the terminology, motives, methods, objectives, and administrative procedures of employers.

Close correlation of concurrent courses is not stressed as strongly in the third and fourth semesters as in the first and second semesters due to the diversity of study in the second year. There are necessary overlapping areas in course content throughout the second year, but in regularly scheduled planning sessions of the staff teaching concurrent second year courses, the most effective material may be prepared for each course to minimize duplication of material and loss of time.

The course, *Communication Skills*, scheduled in the first semester, emphasizes the mechanics of reading, writing, listening, speaking, and reporting. In the third semester these skills are reinforced by the courses, *Technical Reporting* and *Drawing, Sketching and Diagramming*. Instructors in technical courses should set increasingly higher standards of clarity, conciseness and neatness for student work in reporting. Freedom to report on technical subjects of their own choice is likely to add reality and additional motivation for technology students. In the final phases of the 2-year program, the standards of reporting should approach those required by employers. At the same time, instructors should encourage individual style and initiative by allowing as much freedom as possible in reporting, consistent with established school standards. Not all reports should be of a type that requires a disproportionately large number of hours for preparation. The judicious use of both informal and formal reports provides training in both forms with the realism encountered in employment, and limits the time required of students in writing formal reports to a reasonable portion of their time.

The course outlines are concise and comprehensive and are intended as guides rather than as specific instructional plans to be covered in an inflexible order. They represent a judgment on the relative importance of each instructional unit, especially where time estimates are shown. It is expected that the principles outlined in these courses will be supplemented with industrial applications whenever relevant. Field trips add greatly to the effectiveness of the instruction if they are carefully planned in advance so the processes observed will be understood and will be related to the subject material being studied at the time of the trip.

Outside study is a significant part of the student's total program. In this curriculum *two hours of outside study time have been suggested for each hour of scheduled class time.* A typical weekly work schedule for a student in the first semester of this curriculum would be: class attendance, 14 hours; laboratory, 12 hours; and outside study, 28 hours—a total of 54 hours per week. This is a full schedule, but it is not excessive for this type of program. Each subsequent semester's total weekly study load is 54 hours.

It should be noted that no examinations have been scheduled in the outlines. It is clearly intended that time be available for examinations. Therefore, a 17-week semester is assumed, and the outlines are designed to cover a full 16 weeks. The primary objectives of examinations would be to evaluate the student's knowledge and to cause him to make a periodic comprehensive review of the material presented in the course. Examination results also may point out weaknesses in teaching techniques or in coverage of subject matter.

Members of the curriculum advisory committee, especially those representing employers, can help the faculty to decide the amount of emphasis needed on the units presented, time to be spent on each, laboratory facilities and equipment, and textbooks to be used.

A summer session offering courses required by the institution but not included in this curriculum guide could be required of students. A summer session at the end of the second semester would be a desirable time for elective courses to fulfill State or local requirements and to enhance his course of study Chemistry or additional physics studies would be very desirable summer session courses.

The level of instruction in this guide represents a consensus on the level of proficiency required for success in occupations in which a manpower shortage exists today and threatens to become worse in the future. The program is not intended to make the individual proficient in all the duties he might be asked to perform. Proficiency in work of a highly specialized nature such as electronic technology comes only with practice and experience. It is impossible to forecast the exact requirements of any individual, and it is almost impossible to predict accurately the course or rate of change of various technologies. Employers generally recognize that recent engineering graduates may require a year or more to gain the specific training needed to assume their responsibilities. Similarly, employers of newly graduated electronic technicians must generally expect to provide a 3- to 6-month period of orientation to the special situations, processes, and problems encountered on the job. Furthermore, the productive graduate technician will continue to study throughout his career in order to develop to his fullest capabilities.

Suggested Continuing Study

A 2-year curriculum must concentrate on the primary needs of mathematics, science, and the related knowledge and skills in the technical specialty necessary to prepare the student for employment upon graduation.

Obviously, a 2-year program cannot cover in depth all of the subjects which are pertinent to the technology; certain important related subjects may be only casually discussed. Further, the graduate may obtain work in applications so new that adequate coverage in the training program has not yet been developed.

For these reasons some form of continuation of study for graduates of technology programs is desirable. The student can keep abreast of the technical developments in his special field by reading current literature related to the technology, by attending meetings of scientific and technical societies, and by studying on his job. However, such study tends to build on the organized technological base provided by the curriculum he studied. Formal continuation of supplementary courses provides the most efficient and practical means for the graduate technician to add important related areas of knowledge and skill to broaden the base of his initial education. Formally organized courses have the advantage of systematic arrangement of subject matter, disciplined and competent teaching, and class discussions. They may be scheduled for evening or Saturday hours outside of the working day.

Some suggested continuation or extension courses for graduates of this Electronic Technology Curriculum include the following subjects:

Differential Equations
Laplace Transformations and Transient Analysis
Laplace Transformations and Control Systems Analysis
Solid-State Digital Circuits
Microwave Techniques (a continuation of the material covered in the two-year program)
Industrial Television Systems
Physics (covering topics not covered in the curriculum)
Electro-Mechanical Mechanisms
Magnetic Amplifier Design
Transformer Design
Component Evaluation Techniques
Statistics and Quality Control
Missile Guidance Systems
Telemetry Techniques
Lasers and Masers
Other technical courses indicated as desirable by local industry

COURSE OUTLINES

Technical Courses

ELECTRONIC DEVICES

Hours Required

Class, 3; Laboratory, 6

Course Description

This course is an introduction to electronic hardware and its elementary use. It provides the foundation for later courses in electronic circuits and systems by teaching the operational characteristics of electronic devices and by introducing the basic principles and processes involved in each class of devices. Topics studied include the semi-conductor diode and the junction transistor, vacuum tubes, gas tubes, photoelectric devices, zener diodes, and tunnel diodes. These devices are treated in terms of their static characteristics; the load line method of analysis is introduced, and incremental input-output relationships are considered. Analysis involving AC methods is not employed at this time. Elementary applications of devices are presented whenever the student's understanding makes it appropriate or feasable to study application.

During the first several laboratory periods approximately half of the time should be devoted to learning and practicing the use of the slide rule to solve mathematical problems in electronic computation. Sufficient total laboratory time has been allotted to the course to permit teaching the use of this important tool at the beginning, and thus provide for its mastery early in the curriculum so it can be used throughout the entire course of study without taking time from Mathematics I.

The laboratory work introduces the student to electronic devices—what they look like, their names, elementary function, and safe practice in working with them. Elementary skills needed to make desired hook-ups and build-ups are taught early and practiced throughout the course. A laboratory note book is required in this (and all future technical laboratory courses) in which a complete record of observations and notes should be kept. Completeness and orderliness in note recording is emphasized because of their importance to technicians when they are employed.

Major Divisions

	Class Hours	*Laboratory Hours*
I. Semiconductor Principles and the Semiconductor Diode	6	6
II. Thermionic Emission and the Vacuum Diode	3	9
III. Vacuum Tubes	8	9
IV. Gas Tubes	5	9
V. Phototubes	5	9
VI. The Cathode Ray Tube	3	6
VII. Transistors	8	12
VIII. Special Semiconductor Devices	6	9
IX. Power Supply Rectifier Circuits	4	12

I. Semiconductor Principles and the Semiconductor Diode

- A. Units of Instruction
  1. Atomic structure and energy levels
  2. Crystal structure and semiconductors
  3. Electron and hole flow
  4. Impurity effects
  5. Principles of PN junction action
  6. The semiconductor diode
- B. Laboratory Projects
  1. Practice making voltage and current measurement, reading the scales of the instruments, and connecting the instruments in the circuits under test.
  2. Experimentally show by the analogous method that a characteristic of a material may be modified by the addition of a small amount of NaCl to distilled water to modify the conductivity of the water.
  3. Measure the volt-ampere characteristics of the semiconductor diode.

    4. Practice solving electronic computation problems using the slide rule.

II. Thermionic Emission and the Vacuum Diode

- A. Units of Instruction
  1. Electron emission and space current
  2. Emitting materials
  3. Construction and characteristics of the vacuum diode
- B. Laboratory Projects
  1. Measure the volt-ampere characteristics of a vacuum diode.
  2. Design and fabricate AND and OR circuits using semiconductor diodes to demonstrate their use
  3. Continue practice in solving electronic computation problems with the slide rule.

III. Vacuum Tubes

- A. Units of Instruction
  1. Introduction to the triode
  2. Plate characteristics and parameters of the triode
  3. Load line analysis; amplification
  4. The tetrode
  5. The pentode
- B. Laboratory Projects
  1. Measure the characteristics of triode vacuum tubes.
  2. Study a simple amplifier by applying step inputs to the amplifier and observing the change in the output voltage level. Study simple load-line analysis.
  3. Measure the characteristics of screen grid tubes.
  4. Continue practice in solving electronic computation problems with the slide rule.
  5. Experimentally show and describe the characteristics of remote cut-off tubes.

IV. Gas Tubes

- A. Units of Instruction
  1. Electrical conduction in gases
  2. Gas diodes
  3. The thyratron
- B. Laboratory Projects
  1. Measure the volt-ampere characteristics of both hot cathode and cold cathode gas diodes.
  2. Experimentally illustrate the characteristics of simple regulator circuits to demonstrate an important application of gas diodes.
  3. Make an experiment to show the grid control characteristics of a thyratron.

V. Phototubes

- A. Units of Instruction
  1. Principles of photoelectric emission
  2. Illumination units
  3. The high vacuum phototube
  4. The gas phototube
  5. Applications of phototubes
- B. Laboratory Projects
  1. Make simple measurements demonstrating the laws of illumination.
  2. Observe and define the characteristics of a vacuum phototube
  3. Observe and define the characteristics of a gas phototube
  4. Use a gas phototube to demonstrate application of phototubes in simple relay control

VI. The Cathode Ray Tube

- A. Units of Instruction
  1. Principles and construction of the cathode ray tube
  2. Introduction to the oscilloscope
- B. Laboratory Projects
  1. Demonstrate focusing, electrostatic deflection, and magnetic deflection of an electron beam by using a bare CRT tube with electrostatic deflection plates, appropriate power supplies, and a bar magnet.
  2. Learn and practice the use of an oscilloscope for making voltage and frequency measurements.

VII. Transistors

- A. Units of Instruction
  1. Introduction to transistor operation
  2. Characteristic curves and parameters
  3. Amplifying action
  4. The field effect transistor
  5. The unijunction transistor
  6. The phototransistor
  7. Applications
- B. Laboratory Projects
  1. Study transistor characteristics by using a transistor curve tracer.
  2. Determine a transistor's β and α by the voltmeter-ammeter method of measurement.
  3. Investigate simple transistor amplifiers (both common base and common emitter configuration).

VIII. Special Semiconductor Devices

- A. Units of Instruction
  1. The Zener diode
  2. Applications of the Zener diode
  3. The silicon controlled rectifier
  4. Applications of the SCR
  5. Tunnel diode
  6. Light sensitive resistor
  7. The thermistor
- B. Laboratory Projects
  1. Measure the volt-ampere characteristics of a Zener diode.
  2. Demonstrate an important application of Zener diodes using a simple regulator circuit.
  3. Make tests and analyze the control characteristics of a silicon controlled rectifier.
  4. Measure the volt-ampere characteristics of a tunnel diode.

IX. Power Supply Rectifier Circuits

- A. Units of Instruction
  1. The half-wave rectifier
  2. The full-wave rectifier
- B. Laboratory Projects
  1. Make measurements and a simple analysis of a half-wave rectifier circuit.
  2. Perform a similar analysis of a full-wave rectifier circuit.

Texts and References

ALVEREZ *and* FLECKLES. *Introduction to Electron Tubes and Semiconductors*

DEFRANCE. *Electron Tubes and Semiconductors*

LURCH. *Fundamentals of Electronics*

ROMANOWITZ. *Fundamentals of Semiconductor and Tube Electronics*

RYDER. *Engineering Electronics*

SURINA *and* HERRICK. *Semiconductor Electronics*

Visual Aids

Bell System. Any local office of the telephone company.

Bottle of Magic. 20 min., 16 mm., sound, color. Summary: Dramatizes the historical steps in the development of the electron tube and its importance to our civilization in providing communication for police duty, for safer travel, and for entertainment. Bell System Telephone Offices.

Crystals—An Introduction, 25 min., 16 mm., sound, color. Summary: A classroom teaching aid for introducing the subject of crystals. It demonstrates the orderly arrangement of atoms in the crystalline state and the relation of this arrangement to the physical properties of the substance.

DuArt Film Laboratories Inc., 245 West 55th Street, New York, N.Y. 10019

The Cathode Ray Tube: How It Works, 15 min., 16 mm., sound, black and white. Produced for U.S. Department of the Navy, 1943. Made by Jam Handy Organization. Released for public educational use through U.S. Office of Education. Order No. MN 2104-a. Summary: Demonstrates the construction and function of various parts of the cathode ray tube. Explains electrostatic and electromagnetic deflection and how varied currents affect the position of the spot of light on the scope. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360.

The Diode: Principles and Applications, 17 min., 16 mm., sound, black and white. Produced for U.S. Office of Education. Made by Loucks and Norling Studios. (Engineering series. Electronics, No. 2) Order No. OE 176. With instructor's manual. Supplementary filmstrip of same title also available. Summary: Principles of electron flow across a gap; basic features of the diode tube; control of ecletron flow in the tube; photoelectric cells; X-ray tubes; and the diode as a rectifier.

The Electron Theory, 5 min., 16 mm., sound, black and white. Produced for U.S. Department of the Navy. Made by Wilding Picture Productions. (Basic electricity series) Order No. MN 8016-a. Summary: Shows the orbit of electrons around a representative atom; the symbols used for neutral atom, electron, and atom with one positive charge; and normal electron motion and outside force producing electron motion in one direction, called current flow. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360

Transistors: Minority Carriers, 10 min., 16 mm., sound, black and white. Produced for U.S. Department of the Navy. Made by Bray Studios. Order No. MN 8479-c. Summary: Introduces the principle of minority carriers, shows how they produce a small reverse current under normal conditions, and demonstrates the limitations imposed on transistor behavior by minority carriers when the transistor is heated or loaded. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360.

ELECTRONIC AMPLIFIERS

Hours Required

Class, 3; Laboratory, 6

Course Description

This course is a study of the principal forms of transistor and vacuum tube amplifiers, and includes an introduction to power supply filtering. Its underlying philosophy is to provide training in specific representative principles of electronic amplification and to give extensive laboratory experience in the techniques and skills required to use and understand devices encountered in electronic amplification and amplifiers.

The course places heavy emphasis upon transistor circuits in recognition of the place they now occupy in the electronics industry. Thus, where available text material permits, the vehicle for much of the basic study of amplifiers in this course should be the common emitter amplifier, and the vacuum tube common cathode amplifier. Class and laboratory work should be closely coordinated and taught by the same instructor. Laboratory work should expand and build on the *Electronic Devices* course studied the previous semester.

Major Divisions

		Class Hours	*Laboratory Hours*
I.	Amplifier Principles	5	9
II.	Power Supply Filters	3	6
III.	Tube and Transistor Equivalent Circuits	5	9
IV.	Frequency Response	3	6
V.	Transformer Coupling	2	6
VI.	Power Amplifiers	10	18
VII.	Bias Stabilization	5	9
VIII.	Feedback Amplifiers	6	12
IX.	The Emitter Follower Amplifier	3	6
X.	Miscellaneous Tube Amplifiers	2	6
XI.	Wideband Amplifiers	4	9

I. Amplifier Principles
  A. Units of Instruction
    1. Input-output relations in the elementary amplifier
    2. Introduction to RC coupling
    3. The AC load line
    4. Introduction to tube and transistor biasing
  B. Laboratory Projects
    1. Determine the gain and phase relations in an elementary amplifier using an oscilloscope
    2. Study multistage amplifier gain and phase relations after connecting a 2-stage RC coupled amplifier by use of an oscilloscope.
    3. Experimentally demonstrate and measure self biasing in a common cathode amplifier.
    4. Experimentally demonstrate elementary methods of biasing transistor amplifiers.

II. Power Supply Filters
  A. Units of Instruction
    1. The shunt capacitor filter
    2. The series inductor filter
    3. LC filters
  B. Laboratory Projects
    1. By using an oscilloscope, demonstrate and investigate the effects of shunt capacitor filtering.
    2. Determine and plot the characteristics of a series inductor filter.
    3. Show and measure the combined effects of a series-L and a shunt-C filter network.

III. Tube and Transistor Equivalent Circuits
  A. Units of Instruction
    1. Tube equivalent circuits and gain equations
    2. Transistor equivalent circuits
    3. Transistor gain equations, (CB and CE)
    4. Transistor input and output impedances, (CB and CE)
    5. Common base and common emitter characteristics
  B. Laboratory Projects
    1. Calculate, and then verify, experimentally, tube amplifier gain.
    2. Calculate, and then verify, experimentally, transistor amplifier gain.
    3. Measure transistor amplifier input resistance.

IV. Frequency Response

- A. Units of Instruction
  1. Frequency dependent effects in tube and transistor circuits
  2. The amplifier high frequency response
  3. The amplifier low frequency response
- B. Laboratory Projects
  1. Measure the total frequency response of amplifiers as various sizes of coupling capacitors, and by-pass capacitors are employed in the circuit.
  2. Demonstrate and measure the Miller effect in amplifiers.

V. Transformer Coupling

- A. Units of Instruction
  1. The transformer as an amplifier coupling element
  2. Frequency response
- B. Laboratory Projects
  1. Perform tests to show voltage and power relations in transformer coupling.
  2. Measure the frequency response of a transformer coupled amplifier.

VI. Power Amplifiers

- A. Units of Instruction
  1. The class A power amplifier
  2. Amplitude distortion
  3. Push-pull class A operation
  4. Class B power amplifiers
  5. Introduction to phase inverters
  6. The complimentary symmetry amplifier
- B. Laboratory Projects
  1. Predict and experimentally verify power output and efficiency of a Class A power amplifier.
  2. Calculate and measure the degree of distortion in a Class A power amplifier.
  3. Experimentally demonstrate push-pull amplifier operating characteristics.
  4. Study the characteristics of simple phase inverters and self-balancing phase inverters.
  5. Experimentally demonstrate the characteristics of a simple transistor complimentary symmetry amplifier.

VII. Bias Stabilization

- A. Units of Instruction
  1. Operating point variation in transistor amplifiers
  2. Collector feedback stabilization
  3. Emitter resistor stabilization
  4. Stabilizing with temperature sensitive elements
  5. Applications of stabilizing methods
- B. Laboratory Projects
  1. Measure the manufacture spread in transistor characteristics, and the effect of temperature on a transistor's characteristics.
  2. Experimentally analyze the merits of a bias stabilizing circuit.
  3. Design and construct an amplifier with emitter resistor stabilization.

VIII. Feedback Amplifiers

- A. Units of Instruction
  1. General equations and gain stabilization
  2. Input and output impedances
  3. Distortion and noise reduction
  4. Feedback circuit methods
  5. Instability in feedback amplifiers
  6. Multistage feedback
- B. Laboratory Projects
  1. Analyze the gain stability of an amplifier with and without negative feedback.
  2. Experimentally demonstrate and measure frequency response effects of negative feedback.
  3. Show the effect on terminal impedance of an amplifier caused by negative feedback.

IX. The Emitter Follower Amplifier

- A. Units of Instruction
  1. General analysis
  2. Input and output impedance
  3. Applications
- B. Laboratory Projects
  1. Measure the gain and phase characteristics of the emitter follower amplifier.
  2. Experimentally construct and demonstrate a particular application of the emitter follower, the Darlington circuit.

X. Miscellaneous Tube Amplifiers

- A. Units of Instruction

  General characteristics of grounded grid and cathode follower amplifiers
- B. Laboratory Projects
  1. Investigate the basic characteristics of a grounded gird amplifier.
  2. Observe the operating characteristics of a cathode follower amplifier

XI. Wideband Amplifiers
   A. Units of Instruction
      1. High frequency effects in the transistor
      2. High frequency compensation—shunt peaking
      3. High frequency compensation—series peaking
      4. Low frequency compensation
   B. Laboratory Projects
      1. Experimentally demonstrate series and shunt peaking methods of extending the frequency response of amplifiers.
      2. Experimentally analyze negative feedback and simple unilateralization circuits, and show their effects on frequency response of amplifiers.

Texts and References

ALVEREZ *and* FLECKLES. *Introduction to Electron Tubes and Semiconductors*
CUTLER. *Semiconductor Circuit Analysis*
DEFRANCE. *General Electronics Circuits*
EVANS. *Introduction to Electronics*
FITCHEN. *Transistor Circuit Analysis and Design*
HUNTEN. *Introduction to Electronics*
LURCH. *Fundamentals of Electronics*
TERMAN. *Electronic and Radio Engineering*
ZEINES. *Principles of Applied Electronics*

Visual Aids

DuArt Film Laboratories Inc., 245 West 55th Street, New York, N.Y. 10019

Audio Frequency Amplification. Filmstrip 25 fr. 35 mm., black and white. Produced for U.S. Department of the Navy. Made by Jam Handy Organization. Released for public educational use through U.S. Office of Education. Order No. SN 652. Summary: Describes the theory and practice of amplification of the audio wave. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360.

Transistors: High Frequency Operation—Amplifiers and Oscillators. 14 min., 16 mm., black and white, sound. Produced for U.S. Department of the Navy. Order No. MN 8479-e. Summary: Describes how transistors operate in high frequency amplifiers and in oscillator circuits; shows the influence of transit effects in the base; explains collector capacitance and base resistance on high frequency performance. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360.

Transistors: Triode Fundamentals. 11 min., 16 mm., black and white, sound. Produced for U.S. Department of the Navy. Made by Bray Studios. Order No. MN 8479-b. Summary: Shows that junction transistors, or triodes, consists of three sections with the P-N junctions separating them, and discusses the fundamentals of this arrangement as an amplifying device. May be borrowed from the U.S. Department of the Navy, Washingtom, D.C. 20360.

INSTRUMENTS AND MEASUREMENTS

Hours Required

Class, 3; Laboratory, 6

Course Description

A study of electrical measurement and instrumentation devices, transducers, and elements; and the principles underlying their design, use, and relationships. It begins with the mathematical study of probability and error analysis; followed by consideration of the nature and source of errors in measurement and the performance of electrical and electronic instruments. This is followed by a study of specific devices and measuring instruments or classes of measuring devices including basic AC and DC measurement meters, transducers, oscilloscopes, signal generators, tube and transistor testers, and concludes with a study of audio frequency and radio frequency test methods and equipment.

Laboratory work must be coordinated closely with class work. Precision workmanship and techniques in laboratory exercises and an inquiring attitude toward readings or tests must be emphasized and experienced in this course. Since much of the work done by technicians involves measurement, it is imperative that the graduate technician understand the principles and operation of measuring equipment and be able to calibrate electrical and electronic measuring devices, and determine and interpret the accuracy of data. Therefore, attention should be focused on principles underlying instrument construction. The principles do not change, but details and devices used in design of measuring instruments using a particular principle may change with the development of new materials or the adaptation of the instrument to new applications.

Major Divisions

	Class Hours	*Laboratory Hours*
I. Error Analysis	3	6
II. The Basic Meter in DC Measurements	3	18
III. The Basic Meter in AC Measurements	3	0
IV. Comparison Measurement Methods	5	6
V. AC Bridge and Impedance Measurement Methods	4	6
VI. Electronic Voltmeters	5	12
VII. Transducers	3	6
VIII. The Cathode-Ray Oscilloscope	5	6
IX. Signal Generators	3	6
X. Tube and Transistor Testers	3	6
XI. Other Test Equipment	5	9
XII. Audio-Frequency Test Methods	3	9
XIII. Radio-Frequency Test Methods	3	6

I. Error Analysis

- A. Units of Instruction
  1. Indications of precision—significant figures
  2. The normal law of error
  3. Standard deviation and probable error
  4. Mean value and the standard deviation of the mean
  5. Combined errors
- B. Laboratory Projects

  Study the application of error and analysis by making a series of measurements using a crude measuring instrument. Make the same measurements using a precision instrument. Analyze the magnitude and nature of errors, and interpret their significance.

II. The Basic Meter in DC Measurements

- A. Units of Instruction
  1. The meter movement
  2. Voltmeter design
  3. Ammeter design
  4. Ohmmeter design
  5. Multimeters
- B. Laboratory Projects

  Design a simple multimeter around a given meter movement; construct the instrument and check the full-scale accuracy on each scale.

III. The Basic Meter in AC Measurements

- A. Units of Instruction
  - 1. Rectifier type meter
  - 2. Dynamometer-type AC meter
  - 3. Moving-iron type instruments
  - 4. AC voltage ranges
  - 5. AC current ranges
  - 6. Frequency limitations
  - 7. Wattmeters
- B. Laboratory Projects
  - Continuation of the multimeter design and construction project (II above).

IV. Comparison Measurement Methods

- A. Units of Instruction
  - 1. Potentiometer measurements
  - 2. Bridge measurements
  - 3. Instrument calibration using potentiometers
- B. Laboratory Projects
  - 1. Make a calibration of a single scale of a voltmeter against a standard cell using a potentiometer. After preparing a correction curve for this instrument, calibrate a second meter using the first meter and the comparison method. Show importance of standard cell protection.
  - 2. Perform the same two-stage calibration sequence using an ammeter.

V. AC Bridge and Impedance Measurement Methods

- A. Units of Instruction
  - 1. Forms of AC bridges
  - 2. AC null detectors
  - 3. Dissipation factor, leading and lagging current
- B. Laboratory Projects
  - Measure the value of a number of inductors, resistors, and capacitors using an impedance bridge.

VI. Electronic Voltmeters

- A. Units of Instruction
  - 1. Elementary VTVM
  - 2. Bridge type VTVM
  - 3. Logarithmic reading electronic voltmeter
  - 4. Transistorized voltmeters
  - 5. Electrometers
  - 6. Electronic galvanometers
- B. Laboratory Projects
  - 1. Design, construct, and test a simple VTVM.
  - 2. Design, construct, and test a simple transistorized voltmeter.

VII. Transducers

- A. Units of Instruction
  - 1. Thermocouples
  - 2. Resistance thermometers
  - 3. Strain gauges
  - 4. Acceleration measurements
  - 5. Microphones
  - 6. Geiger tubes and scintillation counters
  - 7. Linear differential transformers
- B. Laboratory Projects
  - 1. Measure the sensitivity and directional characteristics of several types of microphones.
  - 2. If a standard microphone is available, calibrate a second microphone using a coupling chamber.

VIII. The Cathode-Ray Oscilloscope

- A. Units of Instruction
  - 1. Basic operation
  - 2. Sweep circuits
  - 3. Complete system
  - 4. Oscilloscope applications
  - 5. Auxiliary equipment
- B. Laboratory Projects
  - Measure and plot both the frequency and phase response of an amplifier.

IX. Signal Generators

- A. Units of Instruction
  - 1. Types of generated signals
  - 2. Audio-frequency generators
  - 3. Radio-frequency generators
  - 4. Sweep-frequency generators
  - 5. Square-wave generators
  - 6. Pulse generators
- B. Laboratory Projects
  - Construct a simple sweep-frequency generator using the capacity of a back-biased diode to shift the frequency. Measure, plot, and analyze the characteristic of this system.

X. Tube and Transistor Testers

- A. Units of Instruction
  - 1. Emission-type tube tester

        2. Dynamic type tube tester
        3. Transistor curve tracer
    B. Laboratory Projects
        Design a simple transistor curve tracer that sweeps one member of the family at a time with a repetition rate of 60 c.p.s. Construct and test the device.

XI. Other Test Equipment
    A. Units of Instruction
        1. Q-meter
        2. R-F impedance bridge
        3. Phase measuring equipment
        4. Counters
        5. Sound level meters
    B. Laboratory Projects
        1. Use the Q-meter to measure Q, inductance, and small capacity values.
        2. Measure the complex impedance of an unknown load versus frequency using an R-F impedance bridge. Note: An interesting load is a 125 uf electrolytic capacitor at elevated frequencies; for example, 4 m.c.

XII. Audio-Frequency Test Methods
    A. Units of Instruction
        1. Amplifier gain and frequency response
        2. Harmonic—distortion testing
        3. Intermodulation—distortion testing
        4. Square—wave testing
    B. Laboratory Projects
        1. Measure the harmonic distortion of an amplifier using a tuned voltmeter or distortion analyzer.
        2. Perform a square wave analysis of an amplifier.

XIII. Radio-Frequency Test Methods
    A. Units of Instruction
        1. Signal tracing
        2. Field strength measurements
        3. Frequency meters
        4. Grid-dip meters
    B. Laboratory Projects
        1. Use the signal substitution method to signal trace a superhetrodyne receiver.
        2. Use a frequency meter to determine the frequency of an oscillator.
        3. Make appropriate measurements using a grid-dip meter.

Texts and References

BARTHOLOMEW. *Electrical Measurements and Instrumentation*
BEERS. *Introduction to the Theory of Error*
BUKSTEIN. *Industrial Electronics Measurement and Control*
CARROLL. *Industrial Process Measuring Instruments*
CERNI *and* FOSTER. *Instrumentation for Engineering Measurement*
CONSIDINE. *Process Instruments and Controls Handbook*
FRIBANCE. *Industrial Instrumentation Fundamentals*
HARRIS. *Electrical Measurements*
MICHELS. *Electrical Measurements and Their Application*
PARTRIDGE. *Principles of Electronic Instruments*
PRENSKY. *Electronic Instrumentation*
STOUT. *Basic Electrical Measurement*
TYSON. *Industrial Instrumentation*
U.S. OFFICE OF EDUCATION. *Instrumentation Technology, a Suggested 2-Year Post High School Curriculum*

Visual Aids

Coronet Instructional Films. Coronet Building, 65 E. South Water St. Chicago, Ill. 60604

Light: Illumination and Its Measurement. 13½ min., 16 mm., sound, black and white or color. Summary: Illustrates the common sources of artificial light and explains their operation. Describes in detail the measurement of light, including luminous intensity, luminous flux, and illumination. Explains and demonstrates such basic terms as candlepower, lumen, and footcandle.

DuArt Film Laboratories Inc., 245 West 55th Street, New York, N.Y. 10019

An Introduction To Radiation Detection Instruments. 17 min. 16 mm., sound, black and white. Produced by U.S. Department of Defense. Released for public educational use through U.S. Office of Education. Summary: Shows the reasons for the existence of radiation detection instruments, as well as the methods employed in their use, and describes several classes of instruments and their specific and general purposes. Produced under the supervision of the Armed Forces Special Weapons Project. May be borrowed from U.S. Army, Signal Officer, Military District of Washington. Washington, D.C. 20310.

Westinghouse Electric Corp., Film Division, No. 3 Gateway Center, Pittsburgh, Pa. 15201.

Heritage Of A Meter. 20 min., 16 mm., sound, color. Produced for Westinghouse Electric Corp. Made by Roland Reed Productions. Summary: Shows the assembly of a Westinghouse magnetic meter. Tells why, with the assets of good engineering and design, this meter will take the hardest service under the most adverse conditions.

COMMUNICATION CIRCUITS

Hours Required

Class, 3; Laboratory, 6

Course Description

This course continues and expands the study of electronic circuits begun in Circuit Analysis AC and DC and introduces circuitry of fundamental importance to radio communication systems. Study of the basic principles and processes used in conventional radio communications follows. Because of the scope and complexity of modern communication systems and equipment, this course emphasizes the principles involved in the use of the components and devices studied as well as providing practice in testing the components and using them in simple relationships in circuits with other units.

Topics include tuned amplifiers, oscillators, amplitude and frequency modulation principles and techniques, communication components, and the principles of receivers and transmitters. It is very important that the laboratory work be closely related to the class study in this course. It is expected that the same instructor will teach both class and laboratory work. Ample laboratory time has been scheduled to provide extensive laboratory experimentation and practice in this fundamental and important subject area.

Major Divisions

	Class Hours	*Laboratory Hours*
I. Tuned Small Signal Amplifiers	5	6
II. Tuned Large Signal Amplifiers	5	12
III. Oscillators	5	12
IV. Amplitude Modulation	5	12
V. Amplitude Modulation Detectors	2	6
VI. Frequency Modulation	4	12
VII. Frequency Modulation Detectors	3	6
VIII. Components in Communications	5	6
IX. Volume and Tone Control Circuits	2	6
X. Receivers (include noise: 2 sessions)	6	12
XI. Transmitters (include coupling circuits)	6	6

I. Tuned Small Signal Amplifiers
- A. Units of Instruction
  1. The tuned vacuum tube amplifier
  2. High frequency effects and neutralization of tube amplifiers
  3. High frequency effects and neutralization of transistor amplifiers
  4. Tuned transistor amplifier circuits
- B. Laboratory Projects

  Predict and experimentally verify prediction of gain and band width of a tuned amplifier.

II. Tuned Large Signal Amplifiers
- A. Units of Instruction
  1. Class C amplifier principles
  2. Class C design methods
  3. Class C amplifier adjustments
  4. Linear Class C amplifiers
  5. Harmonic generators
- B. Laboratory Projects

  Design, construct, neutralize, and test a Class C amplifier

III. Oscillators
- A. Units of Instruction
  1. Oscillator principles
  2. Oscillator circuits
  3. Operating conditions in tube and transistor oscillators
  4. Oscillator stability
  5. Electron coupled oscillators
  6. Parasitic oscillations
  7. Crystal oscillators
- B. Laboratory Projects

  Design, construct, and adjust a power oscillator.

IV. Amplitude Modulation
- A. Units of Instruction
  1. Principles of modulation
  2. Plate and collector modulation
  3. Grid and base modulation

        4. Single sideband methods
    B. Laboratory Projects
        1. Use a spectrum analyzer to investigate the frequency spectra of amplitude modulated waves.
        2. Investigate wave forms and power measurements in collector (plate) modulation.

V. Amplitude Modulation Detectors
    A. Units of Instruction
        1. Introduction to diode detectors
        2. Practical problems in diode detection
        3. Triode detectors
        4. Square-law detection.
    B. Laboratory Projects
        Measure, plot, and analyze diode detector wave forms and input-output relationships.

VI. Frequency Modulation
    A. Units of Instruction
        1. Analysis of frequency and phase modulation
        2. The reactance tube modulator
        3. Phase modulators
    B. Laboratory Projects
        1. Observe, plot, and analyze the frequency spectra of frequency modulated waves.
        2. Study a reactance tube modulator.

VII. Frequency Modulation Detectors
    A. Units of Instruction
        1. The phase-shift discriminator
        2. The ratio detector
        3. The gated beam tube
    B. Laboratory Projects
        1. Experimentally investigate the characterisics of a limiter-discriminator combination.
        2. Perform an experiment using the ratio detector.

VIII. Components in Communications
    A. Units of Instruction
        1. Inductors and magnetic materials in signal circuits
        2. Capacitors and dielectrics at radio frequencies
        3. Shielding of magnetic and electrostatic fields
        4. Microphones
        5. Loud speakers
    B. Laboratory Projects
        1. Measure the inductance and Q of various types of coils at radio frequencies.
        2. Measure the directional characteristics of speakers in different baffles.

IX. Volume and Tone Control Circuits
    A. Units of Instruction
        1. Constant impedance attenuators
        2. Volume control in tube and transistor circuits
        3. Tone control circuits
    B. Laboratory Projects
        Design and test a simple tone control.

X. Receivers
    A. Units of Instruction
        1. Introduction to receiver principles
        2. Frequency translation
        3. Receiver RF and IF considerations
        4. Automatic gain control methods
        5. Receiver tuning and tracking
    B. Laboratory Projects
        1. Align an AM receiver
        2. Make tests on a radio receiver to determine sensitivity and image rejection.

XI. Transmitters
    A. Units of Instruction
        1. Amplitude-modulated transmitters
        2. Frequency-modulated transmitters
        3. Radio-telegraph transmitters
        4. Coupling circuits
    B. Laboratory Projects
        Align a transmitter and make measurements of wave forms for purpose of determining plate efficiency.

Texts and References

CROWLEY *and others. Modern Communications*
CUTLER. *Semiconductor Circuit Analysis*
FITCHEN. *Transistor Circuit Analysis and Design*
GRAY *and* GRAHAM. *Radio Transmitters*
GRIFFITH. *Radio-Electronic Transmission Fundamentals*
HENNEY. *Radio Engineering Handbook*
LOVERING. *Radio Communication*
RYDER. *Electronic Fundamentals and Applications*
SEELY. *Electronic Engineering*
SLURZBERG *and* OSTERHELD. *Essentials of Radio-Electronics*
TERMAN. *Electronic and Radio Engineering*

Visual Aids

DuArt Film Laboratories Inc., 245 West 55th Street, New York, N.Y. 10019.
Basic Principles Of Frequency Modulation. 31 min., 16 mm.,

sound, black and white. Produced by U.S. War Department. Released for public educational use through U.S. Office of Education. Order No. TF 11-2069. Summary: Describe what "FM" is in radio communication, how it is used, and what its advantages and limitations are. May be borrowed from U.S. Army, Signal Officer, Military District of Washington, Washington, D.C. 20310.

Single Sideband Radio: Introduction. 19 min., 16 mm., sound, black and white. Produced for U.S. Marine Corps. Made by U.S. Department of the Navy. Order No. MH 8939. Summary: Explains the theory of single sideband radio techniques and discusses SSB as compared with AM techniques. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360

INTRODUCTION TO COMPUTERS

Hours Required

Class, 4; Laboratory, 3

Course Description

This course introduces the analog computer, covers the operational amplifier, and illustrates how analog computers may be used for the solution of differential equations. Binary arithmetic is covered and the elements of Boolean algebra are taught as a means of introducing digital computer ideas. Circuits used in digital computers are discussed and, finally, simple systems of circuits capable of performing logic operations are covered. It is imperative that electronic technicians be familiar with the principles of both digital and analog computers and the circuits employed in these devices.

Because of the rapid development of the art at this time, and the ever widening applications and implications of computer systems, it is important that the electronic student understand computer principles. As the study proceeds from the simple computer to the complex installations which are becoming parts of control systems, it is necessary to consider the possibilities and the limitations of various types of computers. It is also necessary to become familiar with much auxiliary equipment, such as input-output devices, analog-to-digital and digital-to-analog units, data storage components, and the myriad types of switching and conversion apparatus which have become part of some modern systems.

The advent of computer control of processes along with the use of numerical control for positioning and machine-tool operations, entirely aside from applications in the field of computation and data handling, imposes an ever-greater demand upon the abilities of the technician.

Laboratory work should be coordinated closely with class work.

Major Divisions

	Class Hours	*Laboratory Hours*
I. DC Amplifiers	8	3
II. Analog Computers and Operational Amplifiers	4	3
III. Special Devices	3	3
IV. Simulation and the Analog Computer	4	6
V. Binary Arithmetic and Digital Computers	8	6
VI. Boolean Algebra	12	6
VII. Diode Computer Circuits	4	3
VIII. Multivibrators	10	6
IX. Blocking Oscillators	2	3
X. Magnetic and Dielectric Devices	4	3
XI. Counter and Logic Networks	5	6

I. DC Amplifiers
  A. Units of Instruction
    1. Resistance—coupled amplifier
    2. The Diode—coupled amplifier
    3. The Cathode—coupled amplifier
    4. R-C coupled DC Amplifiers
    5. Automatic amplifier stabilization
    6. Methods of computing: digital, analog, and hybrid
  B. Laboratory Projects
    Design, build, and test a simple cathode-coupled DC amplifier

II. Analog Computers and Operational Amplifiers
  A. Units of Instruction
    1. Criteria of excellence for an operational amplifier
    2. Multiplication by constants
    3. Summing
    4. Solution of linear equations and systems of linear equations
    5. Integrators
    6. Basic parts of an analog computer
    7. Operations which can be performed: summing, integration, differentiation, and theory
  B. Laboratory Projects
    1. Build a simple multiplier.
    2. Design an electrical analog device for adding and subtracting various values. Provide both current and potential outputs which may be multiplied by a constant both more and less than one.

III. Special Devices
  - A. Units of Instruction
    1. Diode function generation
    2. Servo function generation
    3. Servo-multiplier
  - B. Laboratory Projects
    1. Use slide rule as one type of analog computer—distance is the analog of value.
    2. Build a simple diode function

IV. Simulation and the Analog Computer
  - A. Units of Instruction
    1. Indirect simulation
    2. Direct simulation
  - B. Laboratory Projects
    Practice solving simple problems using an analog computer

V. Binary Arithmetic and Digital Computers
  - A. Units of Instruction
    1. The decimal and binary number system
    2. Binary addition and subtraction
    3. Binary multiplication and division
    4. Converting decimal numbers to binary
    5. Negative numbers
    6. Complements
    7. Basic principles of digital computers
  - B. Laboratory Projects
    1. Examine and identify the chief components of a commercial computer
    2. Perform laboratory exercises using binary arithmetic.

VI. Boolean Algebra
  - A. Units of Instruction
    1. The logic of classes
    2. The logic of propositions
    3. Boolean algebra in switching networks
    4. Dual networks
    5. AND, OR, and NOT logic blocks
    6. Principles underlying computer programming
    7. Basic logic circuits—transistor gate logic, multivibrators, triggers, timing, oscillators, ferromagnetic devices
    8. Computer units—counters, coders, storage and shift registers, arithmetic units, memory devices
    9. Input-output devices
    10. Alpha-numeric and binary decimal conversions
    11. Analog-to-digital and digital-to-analog conversions
    12. Magnetic tape recorders: data acquisition and conversion, AM and FM techniques
  - B. Laboratory Projects
    1. Use a digital computer for demonstrating the performance of logic operations
    2. Construct a flow chart showing main interconnections and the directional flow of information in a commercial computer.
    3. Program a simple problem and verify the results.

VII. Diode Computer Circuits
  - A. Units of Instruction
    1. Diode clippers
    2. Diode clamp
    3. Diode AND gate
    4. Diode OR gate
    5. Diode arrays
  - B. Laboratory Projects
    Identify and study diode clippers, diode clamps, and a diode AND gate.

VIII. Multivibrators
  - A. Units of Instruction
    1. Triode, bistable and multivibrator
    2. Transistor, bistable multivibrator
    3. Transistor, monostable multivibrator
    4. Transistor, astable multivibrator
    5. Emitter coupled multivibrators
    6. Direct coupled bistable multivibrator
    7. Negative resistance switching circuits
  - B. Laboratory Projects
    Design, build, and test a transistor bistable unit with diode steering.

IX. Blocking Oscillators
  - A. Units of Instruction
    1. Tube blocking oscillator
    2. Transistor blocking oscillator
  - B. Laboratory Projects
    Investigate and describe the operation and wave forms of a blocking oscillator.

X. Magnetic and Dielectric Devices
  - A. Units of Instruction
    1. Magnetic counters
    2. Magnetic memory arrays
    3. Ferroelectric counter
    4. Ferroelectric memory matrix

- B. Laboratory Projects
    Build and test simple arbitrary base counter using a pulse shaper.

XI. Counters and Logic Networks

- A. Units of Instruction
    1. Binary counters
    2. The arithmetic element
- B. Laboratory Projects
    1. Study examples and applications of half-adder operations
    2. Study examples and applications of full-adder operations
    3. Study examples and applications of half-subtractor operations
    4. Study examples and applications of full-subtractor operations

Texts and References

Arden. *An Introduction to Digital Computing*
Bartee. *Digital Computer Fundamentals*
Blitzer. *Basic Pulse Circuits*
Boschen. *Computer Circuit Projects You Can Build*
Bukstein. *Digital Counters and Computers*
Burroughs Corporation. *Digital Computer Principles*
Chu. *Digital Computer Design Fundamentals*
Harley. *Transistor Logic Circuits*
Hoernes *and* **Heilweil.** *Introduction to Boolean Algebra and Logic Design*
Ketchum *and* **Alverez.** *Pulse and Switching Circuits*
Korn *and* **Korn.** *Electronic Analog Computers*
Mandl. *Fundamentals of Digital Computers*
McCormick. *Digital Computer Primer*
Millman *and* **Taub.** *Pulse and Digital Circuits*
Murphy. *Basics of Digital Computers*
Pettit. *Electronic Switching, Timing, and Pulse Circuits*
Pressman. *Design of Transistorized Circuits for Digital Computers*
Ryder. *Engineering Electronics*
Scott. *Analog and Digital Computer Technology*
Seely. *Electronic Engineering*
Siegel. *Understanding Digital Computers*
Strauss. *Wave Generation and Shaping*

Visual Aids

Bell System. Any local office of the Telephone Company.

Memory Devices. 28 min., 16 mm., color, sound. Summary: Shows information storage devices used in modern computing machine memories and explains how binary information is stored in them.

International Business Machines Corp., Department of Information, 590 Madison Ave., New York, New York, 10022.

The Information Machine. 10 min., 16 mm., or 35 mm., color, sound.

DuArt Film Laboratories Inc., 245 West 55th Street, New York, N. Y. 10019.

Digital Computer Techniques. A series of 6 films produced by U.S. Department of the Navy. 16 mm., color, sound. May be borrowed from the U.S. Department of the Navy. Washington, D.C. 20360.

Computer Logic. 13 min. Order No. MN 8969B. Summary: Explains by means of animation the binary number system. Defines the several meanings of logic as applied to computers, shows the difference between the decimal and binary number systems, explains how binary numbers are constructed, and how arithmetical operations are performed with them. Cites examples of code variations of the binary system.

Computer Logic Symbology. 15 min. Order No. MN 8969C. Summary: Shows the basic U.S. Military standard symbols of the logic elements of computers as an introduction to digital computer logic symbology. Shows the logic elements AND, OR, OR (Exclusive) NOR DELAY, INVERTER, FLIP-FLOP and the way they function in handling electronic signals.

Computer Units. 24 min. Order No. MN 8969D. Summary: Discusses in an introductory way the major units of a digital computer. Describes the input unit and how it reads the problem data and instructions; the output unit and how it delivers problem solutions in some form of output medium; the arithmetic unit and how its basic components work; and the control unit and the purposes of sequencing, clocking, and timing.

Introduction. 16 min. Order No. MN-8969-a. Summary: Provides a general introduction to digital computers; explains the historical origins of calculating devices; points out the differences between analog and digital computers, discussing the principal steps involved in the solution of problems subjected to the digital computing process.

Logic Element Circuits. 16 min. Order No. MN 8969E. Summary: Illustrates how solid state electronics are used in modern computers. Shows diagrams for diode circuits, the P-N-P transistor, and its use in AND, OR, NOR, INVERTER and FLIP-FLOP gates. Shows how the circuits handle the input signals of high and/or low voltages representing binary one's and binary zero's respectively and how the proper output signal is produced.

Programming. 14 min. Order No. MN 8969F. Summary: Defines computer programming, explains what is meant by analyzing the problem, shows how a simple flow chart is prepared with symbols and gives their meaning, and shows how instructions to the computer are encoded in computer language.

Remington Rand, Univac Div., Audio-Visual Engineering Section, Univac Park, St. Paul, Minn. 55116.

Computer Programming. 20 min., 16 mm., black and white, sound.

Introduction to Digital Computers. 25 min., 16 mm., color, sound.

Magnetic Core Memories. 12 min., 16 mm., color, sound

Mines, Mills, And Minutes. 17 min., 16 mm., black and white, sound.

Univac I. 22 min., 16 mm., black and white, sound.

CONTROL CIRCUITS AND SYSTEMS

Hours Required

Class, 3; Laboratory, 3

Course Description

This course is designed to provide the student with an introduction to basic automatic controls. It includes power rectification, inversion, and control; photoelectric and time control of switches; motor controls; and basic open and closed loop servomechanisms.

Because equipment, apparatus, and instrumentation techniques employed today for measurement and control rely, in an increasing degree, upon electronic devices and techniques, it is imperative that the technician understand the various ways in which electronic devices and principles may be employed. The many facets and extremely rapid changes in the field of electronics make it imperative that the material studied illustrate and explain principles which are not dated, but which are basic and universal. The laboratory exercises are chosen and coordinated to strengthen and extend the student's understanding of the principles of automatic controls. A workable compromise has been sought in allotting time for the study of basic control circuits as well as complete control systems.

Major Divisions

	Class Hours	*Laboratory Hours*
I. Power Supplies	9	6
II. Power Control	9	9
III. Photoelectric Applications	3	3
IV. Application of Timers	4	3
V. Relays and Sequential Switches	3	6
VI. Electronic Motor Control	4	6
VII. Transmission of Positional Data	6	6
VIII. Servomechanisms	10	9

I. Power Supplies
- A. Units of Instruction
    1. Half-wave rectifiers
    2. Full-wave rectifiers
    3. Filters
    4. Voltage regulators
    5. Gas diode circuits
    6. Voltage multipliers
- B. Laboratory Exercises
    1. Measure half-wave and full-wave rectifier circuits and determine the Fourier coefficients for the two wave-forms.
    2. Add filters to the above measured rectifier circuits to demonstrate how the Fourier coefficients are modified.
    3. Investigate and explain various series and shunt regulator systems by experimental means.
    4. Construct and test a simple voltage multiplier circuit.

II. Power Control
- A. Units of Instruction
    1. Thyratron and SCR characteristics
    2. Bias control of average current
    3. Phase shift control
    4. Combined bias and phase shift control
    5. Saturable reactors
    6. Ignitrons
    7. Inverters
- B. Laboratory Exercises
    1. Make measurements and plot the control locus of both the thyratron and SCR.
    2. Measure the characteristics of a phase shift bridge.
    3. Design and build SCR and thyratron circuits for the control of AC and DC current.
    4. Demonstrate the control characteristics of a saturable reactor.
    5. Construct and test a transistor inverter.

III. Photoelectric Applications
- A. Units of Instruction
    1. Principles of light
    2. Vacuum photo tubes
    3. Gaseous photo tubes
    4. Photo transistors
    5. Photo resistors
    6. Photoelectric circuits

    7. Photo multipliers
    8. Modulated light applications
    9. Light amplifiers
  B. Laboratory Exercises
    1. Demonstrate and measure the characteristics of various photoelectric devices
    2. Design, construct, and test a simple photo tube relay circuit.
    3. Construct and test a photoelectric measuring circuit
    4. Investigate linear light amplifiers

IV. Applications of Timers
  A. Units of Instruction
    1. DC operated timers
    2. AC operated timers
    3. Time interval measurement
  B. Laboratory Exercises
    1. Measure the characteristics of RC timers
    2. Design and construct equipment to solve a simple sequential timing problem.

V. Relays and Sequential Switches
  A. Units of Instruction
    1. Review of magnetics
    2. Tractive force of an electromagnet
    3. Relay contacts
    4. Design of switching circuits
    5. Sequential switch operation
  B. Laboratory Exercises
    1. Measure the characteristics of a relay.
    2. Solve a switch circuit problem.

VI. Electronic Motor Control
  A. Units of Instruction
    1. DC motor characteristics
    2. Thyratron motor controls
    3. Control of AC motors
  B. Laboratory Exercises
    Perform experiments which demonstrate the control of both DC and AC motors by various means.

VII. Transmission of Positional Data
  A. Units of Instruction
    1. Selsyn motors
    2. Selsyn generators
    3. Control transformer
    4. Differential generator
    5. Amplidynes
    6. Open loop servo systems
  B. Laboratory Exercises
    1. Measure the selsyn output voltage versus shaft position.
    2. Learn the proper interconnection of selsyn components and prove by demonstration.
    3. Experimentally demonstrate the characteristics of an open loop servo system.

VIII. Servomechanisms
  A. Units of Instruction
    1. First order systems
    2. Second order systems
    3. Derivative control
    4. Error-rate control
    5. Integral control
    6. Response of servomechanisms
    7. Stability of servo systems
  B. Laboratory Exercises
    1. Construct a follow-up system
    2. Experimentally demonstrate integral, derivative, and error-rate control.
    3. Study the stability of a system in operation, and introduce variables to test stability

Texts and References

LURCH. *Fundamentals of Electronics*
MANDL. *Industrial Control Electronics*
PLATT. *Magnetic Amplifiers Theory and Application*
REINTJES *and* COATE. *Principles of Radar*
RUITER *and* MURPHY. *Basic Industrial Electronic Controls*
RYDER. *Engineering Electronics*
STUDER. *Electronic Circuits and Instrumentation Systems*

Visual Aids

DeVry Technical Institute, 4141 West Belmont, Chicago, Ill. 60641.

Electronics In Automation. 22 min., 16 mm., black and white or color, sound. Produced by Reid H. Ray. Summary: Shows many opportunities in the coming field of automation electronics. Depicts "push-button plant" of the future and shows applications of electronic controls to production processes. Shows recently-developed computers and other electronic devices, also explains the part automation is expected to play in modern offices.

General Electric Co., 1 River Road, Schenectady, N.Y. 12301.

This Is Automation. 30 min., 16 mm., sound, color. Produced by Raphael G. Wolff Studios. Summary: Defines automation and illustrates industrial applications of the principles of automation in the manufacture and packaging of a variety of products.

COMMUNICATION SYSTEMS

Hours Required

Class, 3; Laboratory, 3

Course Description

This course is an introduction to the principal aspects of communication systems that utilize the basic circuits and processes studied previously in *Communication Circuits* and continues with the study of the principles and techniques of transmission and radiation of electromagnetic energy.

Topics include pulse communication methods, television methods, transmission lines and wave guides, and antennas, including microwave systems.

The laboratory work is intended to strengthen and extend the student's understanding of the principles studied in the class work and to provide experience with some typical components by using them in the laboratory.

Major Divisions

	Class Hours	*Laboratory Hours*
I. Pulse Communications Systems	3	3
II. Television Transmission Systems	9	6
III. Transmission Lines	5	3
IV. Electromagnetic Radiation	3	3
V. Fundamentals of Antennas	3	3
VI. Directional Antennas	4	3
VII. Propagation of Radio Waves	2	0
VIII. Introduction to Microwaves	3	3
IX. Microwave Measurements	4	6
X. Waveguide Components	3	6
XI. Active Microwave Devices	3	6
XII. Microwave Antennas	3	3
XIII. Microwave Systems	3	3

I. Pulse Communications Systems
  A. Units of Instruction
    1. Introduction to pulse communications systems
    2. Pulse code modulation
    3. Noise in pulse communication's systems
  B. Laboratory Projects
    Observe and demonstrate by variations the effects of noise in a pulse modulation system.

II. Television Transmission Systems
  A. Units of Instruction
    1. General description of the television system
    2. Television camera tubes
    3. The television transmitter
    4. The television receiver
    5. Sweep circuit synchronization
    6. Fundamentals of color television
  B. Laboratory Projects
    1. Investigate and diagram the various waveforms in a television receiver.
    2. Investigate and demonstrate various synchronizing methods.

III. Transmission Lines
  A. Units of Instruction
    1. Wave propagation on the transmission line
    2. Characteristic impedance
    3. The terminated transmission line
    4. Transmission line charts
    5. Transmission lines as circuit elements
    6. Impedance matching in transmission lines
  B. Laboratory Projects
    Measure the standing wave ratio and measure the impedance of a transmission line.

IV. Electromagnetic Radiation
  A. Units of Instruction
    1. Electric and magnetic fields and radiation
    2. Reflection and refraction
    3. Interference and diffraction
  B. Laboratory Projects
    1. Perform experiments demonstrating the effects of reflection, refraction, interference, and diffraction.
    2. Use a fast oscilloscope and fast-rise pulse to show reflections from impedance mismatch.

V. Fundamentals of Antennas
- A. Units of Instruction
  1. Radiation from the elementary dipole
  2. Characteristics of wire radiators remote from ground
  3. Grounded antennas
  4. Radiation resistance and radiated power
- B. Laboratory Projects
  - Perform and plot field strength measurements.

VI. Directional Antennas
- A. Units of Instruction
  1. Directive gain of antennas
  2. Directional characteristics of wire radiators
  3. Arrays of antennas
  4. Impedance matching and phasing systems
  5. Reflectors and parasitic elements
  6. Miscellaneous antennas
- B. Laboratory Projects
  - Perform experiments demonstrating the effects of antenna phasing.

VII. Propagation of Radio Waves
- A. Units of Instruction
  1. The space wave and the ground wave
  2. Atmospheric effects
  3. Description of the ionosphere
  4. Ionospheric effects on radio wave propagation

VIII. Introduction to Microwaves
- A. Units of Instruction
  1. The concept of a waveguide
  2. Types of waveguides
  3. Modes of operation
- B. Laboratory Projects
  1. Measure the wavelength along a waveguide
  2. Measure and explain waveguide attenuation.

IX. Microwave Measurements
- A. Units of Instruction
  1. Measuring microwave power
  2. Measuring frequency and wavelength
  3. Measuring standing wave ratio and computing reflection coefficient
  4. Measuring microwave impedance
- B. Laboratory Projects
  1. Measure the standing wave ratio waveguide.
  2. Measure and explain impedance in a waveguide

X. Waveguide Components
- A. Units of Instruction
  1. Waveguide attenuators
  2. Directional couplers
  3. Waveguide tuners
  4. Waveguide junctions
  5. Microwave mixers and detectors
  6. Detector mounts
  7. Circulators
  8. Switches
- B. Laboratory Projects
  1. Measure the characteristics of a directional coupler.
  2. Practice making microwave tuner adjustments.
  3. Determine the characteristics of microwave mixer and detector.

XI. Active Microwave Devices
- A. Units of Instruction
  1. Traveling wave tube
  2. Klystrons
  3. Magnetrons
  4. Tunnel diodes
  5. Maser
  6. Laser
  7. Parametric amplifiers
- B. Laboratory Projects
  1. Determine the characteristics of a klystron by measurement.
  2. Design, construct, and test a tunnel diode oscillator.
  3. Test a parametric amplifier, and explain how it functions.

XII. Microwave Antennas
- A. Units of Instruction
  1. Propagation of microwaves
  2. Primary microwave antennas
  3. Secondary microwave antennas
  4. Microwave antenna measurements
- B. Laboratory Projects
  1. Measure gain and beam width of a primary antenna.
  2. Measure gain and beam width of a secondary antenna.

XIII. Microwave Systems
- A. Units of Instruction
  1. Microwave receivers

    2. Microwave transmitters
    3. Microwave system applications
    4. System measurements

B. Laboratory Projects
    1. Demonstrate the characteristics of an I.F. amplifier and an AFC unit.
    2. Perform measurements to determine receiver sensitivity and system performance.

Texts and References

Crowley *and others. Modern Communications*
Griffith. *Radio-Electronic Transmission Fundamentals*
Henney. *Radio Engineering Handbook*
Kraus. *Antennas*
Lance. *Introduction To Microwave Theory and Measurements*
Terman. *Electronic and Radio Engineering*
Tinnell. *Introductory Microwave Techniques*
Welch. *Wave Propagation and Antennas*
Wheeler. *Introduction to Microwave*

Visual Aids

Bell System. Any local office of the telephone company.

Coaxial And Microwave Miracles. 11 min., 16 mm., sound, black and white. Summary: In this film, Dr. M. E. Strieby demonstrates what a coaxial cable is and why it is economical. The behavior of microwave transmission is demonstrated and explained by using actual models.

McGraw-Hill Book Co., Text Film Dept., 30 West 42nd Street, New York, N.Y. 10036.

Television. (6 films) Sound, black and white. A set of 6 films and 6 filmstrips, correlated with the book "Basic Television" by Brob. Summary: Demonstrates and explains the basic principles and servicing of television receivers.

Antenna Installation	12 min.
Deflection Circuits	11 min.
Localizing Troubles	11 min.
Practical TV Alignment	16 min.
Television Receivers	7 min.
Television System	14 min.

ELECTRONIC DESIGN AND FABRICATION

Hours Required

Class, 1; Laboratory, 5

Course Description

A course to exercise the student's knowledge of electronics through individual or small group projects and to direct his attention and exercise his skills toward some of the real problems of electronic circuit or system fabrication. It provides time and opportunity for the student to work on the design, fabrication, assembly, and testing of some electronic device, circuit, unit, or system of his choice. Its purpose is to promote independent study, initiative, and the assumption of responsibility and work without specific instruction upon initiation of the project. The student will draw upon all of his previous courses of study in order to arrive at satisfactory project completion. It will be necessary for the student to select materials, devices, components, means of fabrication, sizes and dimensions, tests, and method of performance evaluation.

Projects approved for this course should be chosen carefully to exercise the various skills, techniques, and competencies required of electronic technicians when they enter employment. For this reason, it is well to consider that major laboratory time and strong emphasis have *not* been given to fabrication skills. Therefore, it is imperative that special attention be given to the exercise of careful workmanship and techniques in the fabrication part of the project. This will probably require some instructional guidance in the use of tools and equipment during fabrication. Each project should require the making of some simple components.

It is desirable that a variety of projects be selected by members or small groups of the class because usually there is an interchange of experience among students working singly or in groups on various projects which can prove stimulating and informative for them. It may be useful to assign projects that terminate in a piece of equipment useful to the department. This technique usually creates much more interest on the part of the student than an arbitrarily assigned problem of value only for the project grade.

The lecture hour for this course may be used as a half-hour preparation period prior to laboratory periods to give direction to the laboratory work and as a consulting time on particular projects. Laboratory time suggested below for various phases of the different projects may vary, depending on the project or the student. The suggested division of time is provided as a planning guide and is not an arbitrary requirement.

Major Divisions

	Class Hours	*Laboratory Hours*
I. Conference with faculty advisor at beginning and during project	16	0
II. Design, fabrication, and testing or evaluation, and reporting		
(a) Selection of project and preliminary conceptual study and planning		4
(b) Design of the device, circuit unit or system, including detailed conceptual study and plan, study calculations, proof of probable feasibility, and choice of fabrication technique		13
(c) Making drawings, diagrams, and sketches covering the entire project, step-by-step in detail		8
(d) Fabricating the project		38
(e) Testing and evaluation, and possible modification of the project		8
(f) Final formal report (complete with test or evaluation data and results)		10

Some Further Suggestions:

To provide a range and variety of projects for a class, representative projects might be selected from the following major areas in the electronic field, and chosen to exercise the particular principles, skills, techniques, and competencies they encompass:

1. Conventional electronic circuit fabrication
2. Design of electronic units ("packaging")
3. Printed circuit fabrication techniques
4. High-Density fabrication techniques
5. Utilization of machine and hand tools in circuit fabrication
6. Casting and foaming circuits

Some examples of projects (in the foregoing fields which might be built):

1. High-gain amplifiers
2. Wide-band amplifier
3. Schmitt trigger circuit coupled to an emitter follower to be used in conjunction with a sinewave oscillator to produce a square wave output
4. Analog computer circuits
5. Digital logic blocks to be used in building up logic networks
6. Microwave components (slatted lines, horn antennas, or similar devices)
7. Units utilizing printed circuits (circuits printed as part of the project)
8. Minimum size and weight (package) electronic device

Texts and References

DUMMER. *Electronic Equipment Design and Construction*

SACHS. *Principles and Methods of Sheet Metal Fabricating*

SCHLABACH *and* RIDER. *Printed and Integrated Circuitry*

Note: In addition to the foregoing:

A. Any previously referenced texts and references
B. Any pertinent data in the library
C. Scientific and technical journals
D. Trade and manufacturing periodicals
E. Manufacturers' data sheets, operation manuals, and specifications
F. Any pertinent information from other sources.

Visual Aids

Bray Studios, Inc., 729 7th Ave., New York, N.Y. 10036

The Printed Circuit Story. 25 min., 16 mm., color, sound. Produced in cooperation and collaboration with the Institute of Printed Circuits. Summary: Shows how printed circuits are manufactured from the base laminate through component installation on etched and plated circuit boards. Introduces recommended tools and helpful items for the servicing of printed circuits as well as repairability techniques according to accepted industry standard practices

INTRODUCTION TO NEW ELECTRONIC DEVICES

Hours Required

Class, 2; Laboratory, 0

Course Description

A study of new developments in materials or techniques for electronic devices and of applications of electronic devices, units, or systems in new fields or in new ways. It requires the instructional staff to keep up-to-date by reading the current literature and to construct demonstration materials for teaching new concepts. Students are required also to search the current new literature, thus strengthening their information-seeking and investigative competencies. A written report covering a new development, preferably one which especially interests him, should be expected from each student.

Even though this course may seem demanding for the instructional staff, they should welcome it for at least two important reasons:

(1) They are motivated to become familiar with new devices and applications in the field and to teach them to student technicians.

(2) They are required to organize the newly developed material into a teachable form, to demonstrate, and to teach it; this permits new developments to take their proper place in *regular courses each year*. This avoids the alternative of allowing the technical curriculum material to become obsolete in places, requiring the instructor to undertake the difficult task of a total revision of several courses at any time.

The particular subjects taught will be dependent on the judgment of the instructional staff. Lecture and demonstration materials will usually come from current scientific and technical journals and trade publications. To prepare demonstration materials for class poses a special challenge to the staff but the students could be called upon to share in some cases. The limited availability and high costs of new devices may often be overcome, for purposes of this class, by resourcefully simulating the construction or function of the device; or better still, obtaining information about, and possibly prototypes from the developers or researchers who have announced these devices or will produce them.

It is highly advisable to rotate the teaching of this course to all the technical staff members. Such rotation of staff will tend to insure that the material does flow from this course into other courses in the curriculum. It also encourages the whole technical staff to keep their knowledge of electronics current.

The subjects included as major divisions in this outline are only indicative of the subjects that could appear in such a course at this time, (1965). Hours for major subjects will be variable as needed in light of importance of new developments.

Major Divisions

	Class hours
I. New Electronic Devices	(vary as required by new subject matter)
II. New Applications of Electronics	

I. New Electronic Devices
  A. Possible Subdivisions
    1. Solidstate components
    2. Transducers
    3. Molecular electronic devices
  B. Typical Subjects
    1. Lasers
    2. Masers
    3. Tunnel diodes
    4. Field effect transistors
    5. Strain gages
    6. "Grown" circuits
    7. New materials and components

II. New Electronic Applications
  A. Possible Subdivisions
    1. Acoustical-electronic applications
    2. Communications applications
    3. Electromechanical applications
    4. Medical-electronic applications
    5. Nuclear-electronic applications
    6. Optical-electronic applications
    7. Thermo-electronic applications
  B. Typical Subjects
    1. Laser welding
    2. Superconductivity devices

3. Measuring instruments
4. Laser and maser communications

Typical Periodical Sources:

Advances in Electronics and Electron Physics
American Journal of Physics
American Journal of Science
Bell Laboratories Record
Computer Journal
Control Engineering
Electrical Engineering
Electronics
Instruments and Automation
International Science and Technology
ISA Journal
Journal of Applied Physics
Journal of Engineering Physics
Microwave Journal
Physics Today
Proceedings of the Institute of Electronic and Electrical Engineers
Reports on Progress in Physics
Review of Modern Physics
Semiconductor Products and Solid State Technology
Solid State Communications
Solid State Design
Solid State Electronics
Trend in Engineering
Wireless World

Mathematics and Science Courses

TECHNICAL MATHEMATICS I (Algebra and Trigonometry)

Hours Required

Class, 5; Laboratory, 0.

Course Description

This first course in mathematics is designed to insure that the student has the mathematics necessary to understand and work with the principles covered in the technical courses. Care has been taken to develop the various topics in mathematics in this course before the student is required to use them in the concurrent technical courses.

As the various topics are introduced, the meaning and underlying principles of each and the role each plays in electronic technology should be considered before the subject proper is explored. Practical problems following the exposition of each major topic will help to motivate the student and will strengthen his understanding of the principles involved. Insofar as possible, the course should draw upon physical relationships which are considered in *Applied Physics for Electronics I.*

The first mathematics course also prepares the student for Technical Mathematics II by introducing the ideas of function notation and graphing techniques.

Note: Use of the slide rule is taught during the first few laboratory periods of the concurrent course *Electronics Devices* to provide the student with skill in its use as a tool in solving mathematical problems without delaying his progress in learning fundamental mathematical principles necessary to understand electrical and electronic topics studied in his technical courses.

Major Divisions

	Class hours
I. Fundamental Concepts and Operations	8
II. Functions and Graphs	5
III. Trigonometric Functions	5
IV. Linear Equations and Determinates	6
V. Factoring and Fractions	6
VI. Quadratic Equations	4
VII. Trigonometric Functions of Any Angle or Number	4
VIII. Vectors and Triangles	6
IX. Graphs of the Trigonometric Functions	6
X. Exponents and Radicals	5
XI. The *j*-Operator	5
XII. Logarithms	5
XIII. Solving Equations and Systems of Equations	5
XIV. Properties of the Trigonometric Functions	6
XV. The Inverse Trigonometric Functions	4

I. Fundamental Concepts and Operations

Units of Instruction

1. Numbers and literal symbols
2. Fundamental laws of algebra
3. The law of signs
4. Operations with zero
5. Exponents and radicals
6. Addition and subtraction of algebraic expressions
7. Multiplication and division of algebraic expressions
8. Equations and formulas
9. Problems
10. Questions
11. Examination

II. Functions and Graphs

Units of Instruction

1. Functions
2. Cartesian Coordinates
3. Graphing functions
4. Zeros of a function
5. Problems
6. Questions
7. Examination

III. Trigonometric Functions

Units of Instruction

1. Angles
2. The right triangle
3. The trigonometric functions
4. Values of the trigonometric functions
5. Use of tables
6. Problems
7. Questions
8. Examination

IV. Linear Equations and Determinates

Units of Instruction

1. Linear equations
2. Graphical solution of systems of two linear equations in two unknowns
3. Algebraic solution of systems of two linear equations in two unknowns
4. Solution by determinates of systems of two linear equations in two unknowns
5. Algebraic solutions of three linear equations in three unknowns
6. Solution by determinates of systems of three linear equations in three unknowns
7. Problems
8. Questions
9. Examination

V. Factoring and Fractions

Units of Instruction

1. Special Products
2. Factoring
3. Simplifying fractions
4. Multiplication and division of fractions
5. Addition and subtraction of fractions
6. Problems
7. Questions
8. Examination

VI. Quadratic Equations

Units of Instruction

1. Quadratic equations. Solution by factoring.
2. Completing the square
3. The quadratic formula
4. Problems
5. Questions
6. Examination

VII. Trigonometric Functions of Any Angle or Number

Units of Instruction

1. Signs of the trigonometric function
2. Radian
3. Applications of the use of radian measure
4. Trigonometric functions of any angle
5. Problems
6. Questions
7. Examination

VIII. Vectors and Triangles

Units of Instruction

1. Vectors
2. Application of Vectors
3. Oblique triangles
4. The law of sines
5. The law of cosines
6. Problems
7. Questions
8. Examination

IX. Graphs of the Trigonometric Functions

Units of Instruction

1. Graphs of $Y = A \sin x$ and $Y = A \cos x$
2. Graphs of $Y = A \sin bx$ and $Y = A \cos bx$
3. Graphs of $Y = A \sin (bx + c)$ and $Y = A \cos (bx + c)$
4. Graphs of $Y = \tan x$, $Y = \cot x$, $Y = \sec x$, $Y = \csc x$
5. Applications of the trigonometric graphs.
6. Composite trigonometric curves
7. Problems
8. Questions
9. Examination

X. Exponents and Radicals

Units of Instruction

1. Positive integers as exponents
2. Zero and negative integers as exponents
3. Fractional exponents
4. Simplest radical form
5. Addition and subtraction of radicals
6. Multiplication and division of radicals
7. Problems
8. Questions
9. Examination

XI. The *j*-Operator

Units of Instruction

1. Imaginary and complex numbers
2. Operations with complex numbers
3. Graphical representation of complex numbers
4. Polar form of a complex number

5. Products, quotients, powers, and roots of complex numbers
6. Problems
7. Questions
8. Examination

XII. Logarithms

Units of Instruction

1. Exponential and logarithmic functions
    a. Discussion of the design of a slide rule as a logarithmic device.
2. Graphs of $Y = b^x$ and $Y = \log_b X$
3. Properties of logarithms
4. Logarithms to the base 10
5. Computations using logarithms
6. Problems
7. Questions
8. Examination

XIII. Solving Equations and Systems of Equations

Units of Instruction

1. Graphical solution of systems of equations
2. Algebraic solution of systems of equations
3. Equations in quadratic form
4. Equations with radicals
5. Exponential and logarithmic equations
6. Problems
7. Questions
8. Examination

XIV. Properties of the Trigonometric Functions

Units of Instruction

1. Fundamental trigonometric identities
2. Sine and cosine of the sum and difference of two angles
3. Double angle formulas
4. Half angle formulas
5. Trigonometric equations
6. Problems
7. Questions
8. Examination

XV. The Inverse Trigonometric Functions

Units of Instruction

1. Inverse trigonometric functions
2. Principal values
3. Graphs of the inverse trigonometric functions
4. Problems
5. Questions
6. Examination

Texts and References

ADAMS. *Intermediate Algebra*
COMBELLACK. *Introduction to Elementary Functions*
COOKE. *Basic Mathematics for Electronics*
HALL *and* KATTSOFF. *Unified Algebra and Trigonometry*
JUSZLI *and* ROGERS. *Elementary Technical Mathematics*
LENNHARDY. *College Algebra*
RICE *and* KNIGHT. *Technical Mathematics with Calculus*
SCHWARTZ. *Analytic Geometry and Calculus*
WASHINGTON. *Basic Technical Mathematics with Calculus*

Visual Aids

Coronet Films, Inc., Coronet Building, Chicago, Illinois, 60604

Pythagorean Theroem, The Cosine Formula, 1960, 5½ minutes, 16 mm., sound, black and white, $30.00 Shows how the Pythagorean Theorem may be applied to acute angled triangles in addition to right triangles and how this approaches a right angle and its cosine approaches zero, so that the Pyhtagorean Theorem reappears.

Pythagorean Theorem, Proof By Area. 5½ min., 16 mm., sound, black and white, $30.00 Animated diagrams demonstrate the principles of geometric movement and transformation by showing how the square of each side of a right triangle may be transformed to a parallelogram of equal area and how these may be proved to be equal in area to the square of the hypotenuse.

International Film Bureau, Inc., 332 South Michigan Avenue, Chicago, Illinois, 60604.

Axioms In Algebra, 13 minutes, 16 mm., sound, color, purchase $135.00, rent $6.00. Produced by Visual Education Films. Presents the fact that an axiom is a statement accepted as true without proof, and then demonstrates the addition, subtraction, multiplication and division axioms as applied to solving practical problems by utilizing pictographic equations. Additional examples demonstrate how the root of each equation is used to check the solution. Uses a schematic balance to illustrate the axioms in even simpler terms and to further demonstrate order to preserve the equality. These operations include raising members to like powers and extracting like roots.

DuArt Film Laboratories, Inc., 245 West 55th Street, New York, N.Y.

An Introduction to Vectors: Coplaner Concurrent Forces, 22 minutes, 16 mm., sound, black and white. Made by Loucks and Norling Studios. (Engineering series. Fundamentals of mechanics.) Order No. OE 361. Supplemented by filmstrip with same title and instructor's manual. Summary: Explains the meaning of scalar and vector quantities, how to add scalars and vectors, methods of vector composition and vector resolution, relationship between vector composition and vector resolution, and how vectors may be used to solve engineering problems.

The Slide Rule: The "C" And "D" Scales, 24 minutes, 16 mm., sound, black and white. Made by Loucks and Norling Studios. (Engineering series) Order No. OE 179. Supplemented by filmstrip with same title and instructor's manual. Summary: Shows the purpose of the slide rule, parts of the rule, how to use the "C" and "D" scales in the multiplication and division of numbers.

The Slide Rule: Proportion, Percentage, Squares, And Square Roots, 21 minutes, 16 mm., sound, black and white. Made by Loucks and Norling Studios. (Engineering series) Order No. OE 354. Supplementary filmstrip of same title also available with instructor's manual. Summary: Shows how to use the "C" and "D" scales of the slide rule to calculate proportions and percentages, how to read the "A" and "B" scales, and how to calculate squares and square roots.

TECHNICAL MATHEMATICS II (Applied Calculus)

Hours Required

Class, 4; Laboratory, 0.

Course Description

This course is a continuation of Technical Mathematics I. The student studies the elements of analytic geometry prior to his introduction to calculus. The idea and principles of both differentiation and integration are developed and applied to technical problems. The course concludes with an introduction to Fourier analysis as it applies to an electronic problem.

There should be a close correlation between this course and *Applied Physics for Electronics II* and *Circuit Analysis*. Reasonable competency in the use of these mathematical concepts and processes prepares the student to work effectively with the engineer, to read technical publications, and to apply these mathematical tools to the solution of technical problems which he may be expected to encounter as an electronic technician.

Major Divisions

	Class hours
I. Elements of Analytic Geometry	8
II. Derivatives and Applications	16
III. Integration and Applications	16
IV. Differentiation of Transcendental Functions	8
V. Integration Techniques	8
VI. Fourier Analysis	8

I. Elements of Analytic Geometry

Units of Instruction

1. The straight line
2. The circle
3. The parabola
4. The ellipse
5. The hyperbola
6. Polar coordinates
7. Problems
8. Questions
9. Examination

II. Derivatives and Applications

Units of Instruction

1. Limits
2. The slope of a tangent to a curve
3. The derivative
4. Derivatives of polynomials
5. Derivatives of products and quotients of functions
6. The derivative of a power of a function
7. Curve tracing
8. Maximum and minimum problems
9. Problems
10. Questions
11. Examination

III. Integration and Applications

Units of Instruction

1. Differentials and inverse differentiation
2. The indefinite integral
3. The area under a curve
4. The definite integral
5. Finding areas by integration
6. Tropezoidal rule for approximating areas
7. Volumes by integration
8. Applications of the integral
9. Problems
10. Questions
11. Examination

IV. Differentiation of Transcendental Functions

Units of Instruction

1. Derivatives of the sine and cosine functions
2. Derivatives of the other trigonometric functions
3. Derivatives of the inverse trigonometric functions
4. Derivatives of the logarithmic function
5. Derivative of the exponential function
6. Applications
7. Problems
8. Questions
9. Examination

V. Integration Techniques

Units of Instruction

1. The general power formula
2. The logarithmic and exponential form
3. Basic trigonometric forms
4. Integration by parts
5. Integration by substitution
6. Use of the tables
7. Problems

    8. Questions
    9. Examination

VI. Fourier Analysis
  Units of Instruction
    1. Introduction to series
    2. Developing the Fourier Series
    3. Even and odd functions
    4. Application of the Fourier Series
    5. Problems
    6. Questions
    7. Examination

Texts and References

ADAMS. *Applied Calculus*
COOKE. *Basic Mathematics for Electronics*
JUSZLI. *Analytic Geometry and Calculus*
RICE *and* KNIGHT. *Technical Mathematics with Calculus*
RICHMOND. *Calculus for Electronics*
SAGAN. *Integral and Differential Calculus*
SMITH *and others*. *Calculus*
SPIEGAL. *Applied Differential Equations*
TUITES. *Basic Mathematics for Technical Courses*
WASHINGTON. *Basic Technical Mathematics with Calculus*

PHYSICS FOR ELECTRONICS I (Electricity)

Hours Required

Class, 3; Laboratory, 6.

Course Description

This study of electricity lays the groundwork for the electronic courses and advanced circuit analysis courses. The student advances from a study of the atomic theory and structure of matter to the fundamentals of current flow, thence through a study of the characteristics of simple DC circuits, to magnetic circuits and circuit theorems. Topics are arranged so the basic ideas are covered in this course before they are used in analyzing electronic elements and components in the *Electronics Devices* course which is taught concurrently.

The laboratory experience in this course begins with a study of the use of soldering irons and other commonly used tools, basic wiring techniques, the use of fundamental measuring tools and instruments, and then proceeds to the verification of electrical theory through laboratory experimentation. Manual skills and the practice of safety and good workmanship must be developed early to insure good performance in laboratory work throughout the curriculum. A major purpose of developing manual skills during the early laboratory periods is to allow time for the theory learned in physics and mathematics classes to be sufficiently developed to insure that later laboratory work can be used effectively to illustrate and demonstrate scientific principles learned in class.

Major Divisions

	Class Hours	*Laboratory Hours*
I. Fundamentals and Matter and Atomic Structure	9	18
II. Ohm's Law and the Electric Circuit	10	21
III. Power	3	6
IV. Electromagnetism and Magnetic Circuits	10	21
V. Electromagnetic Induction	6	12
VI. Capacitance	6	12
VII. Alternating Voltages and Currents	4	6

I. Fundamentals of Matter and Atomic Structure

- A. Units of Instruction
  1. Matter
  2. Structure of the atom
  3. Ionization
  4. Nature of electricity
  5. Conductors, insulators, and current
  6. Electromotive force
  7. Sources of voltage
  8. Units
  9. Elements of an electric circuit
  10. Resistance
- B. Laboratory Projects
  1. Study and practice splicing of wires and using the soldering iron.
  2. Learn and practice wiring of a chassis and use of soldering guns.
  3. Learn how to use the color code.
  4. Learn how to use an ohmmeter.
  5. Learn how to connect and read various electric meters.
  6. Measure a linear resistance volt-ampere characteristic.

II. Ohm's Law and the Electric Circuit

- A. Units of Instruction
  1. The electric circuit
  2. Ohm's law
  3. Applications of Ohm's law
  4. The series circuit
  5. The parallel circuit
  6. The series-parallel circuit
- B. Laboratory Projects
  1. Investigate and demonstrate nonlinear resistance and dynamic resistance.
  2. Investigate and demonstrate a series circuit composed of linear elements.
  3. Investigate and demonstrate series circuits composed of linear and non-linear elements.
  4. Study parallel connection of linear resistance.
  5. Demonstrate, plot, and account for measurement discrepancies in simple meter circuits.
  6. Study and explain methods of error analysis and methods of error reduction.

III. Power
- A. Units of Instruction
  1. Work and energy
  2. Power
  3. Maximum power transfer
  4. Efficiency
- B. Laboratory Projects
  1. Study power dissipation in series circuits.
  2. Investigate and demonstrate the effect of temperature on resistance.
  3. Investigate and demonstrate Thevenin's theorem and source resistance.
  4. Investigate and demonstrate Norton's theorem and constant current sources.

IV. Electromagnetism and Magnetic Circuits
- A. Units of Instruction
  1. The magnetic field
  2. Electromagnetism
  3. The magnetic field around a coil
  4. Magnetomotive force, flux and reluctance
  5. Theory of magnetism and magnetic materials
  6. The magnetic circuit
  7. Ohm's law for magnetic circuits
  8. Magnetization curves
  9. The series magnetic circuit
  10. The parallel magnetic circuit
  11. The series-parallel magnetic circuit
  12. Losses in magnetic materials
- B. Laboratory Projects
  1. Perform experiments demonstrating maximum power transfer and transfer efficiency.
  2. Perform several simple experiments as an introduction to magnetism.
  3. Experimentally run a hysteresis loop of a sample.

V. Electromagnetic Induction
- A. Units of Instruction
  1. Electromagnetic induction
  2. Lenz's law
  3. Inductance, self-inductance, mutual inductance
  4. Coils in series and parallel
  5. Time constants in inductive circuits
- B. Laboratory Projects
  1. Demonstrate and determine the characteristics of series and parallel inductors.
  2. Demonstrate and develop data on R.L. time constants.

VI. Capacitance
- A. Units of Instruction
  1. The electrostatic field
  2. Capacitance and capacitors
  3. Capacitance in series and parallel
  4. Time constants in capacitive circuits
- B. Laboratory Projects
  1. Measure and demonstrate the characteristics of capacitors in series and parallel.
  2. Learn to use the universal R.C. time constant curve.
  3. Do laboratory exercises in solving R.C. time constant problems.
  4. Measure R.C. time constants.

VII. Alternating Voltages and Currents
- A. Units of Instruction
  1. Frequency and periodicity
  2. Sinusoidal voltages and currents
  3. Phase angle and phase difference
  4. The average and effective values of a sine wave
- B. Laboratory Projects
  1. Make measurements of AC voltages with an oscilloscope.
  2. Make phase and frequency measurements with an oscilloscope.

Texts and References

BEISER. *The Mainstream of Physics*

BLACKWOOD *and others*. *General Physics*

GILLIE. *Electrical Principles of Electronics*

HARRIS *and* HEMERLING. *Introductory Applied Physics*

JACKSON. *Introduction to Electric Circuits*

MORECOCK. *Alternating-Current Circuits*

OPPENHEIMER *and* BORCHES. *Direct and Alternating Currents*

RESNICK *and* HALLIDAY. *Physics for Students of Science and Engineering*

SEARS *and* ZEMANSKY. *College Physics*

——— *and* ———. *University Physics*

Visual Aids

Bell System Telephone Company. Request from any local Bell System Telephone business office.

Domains And Hysteresis In Ferromagnetic Materials, 38½ minutes, 16 mm., sound, color. This film develops the theories that are fundamental to understanding hysteresis in magnetically soft and magnetically hard materials and shows pictures of domain wall motion. It includes a full discussion of the origin of the coercive force.

General Electric Company, 1 River Road, Schenectady, New York, 12301; and Handel Film Corporation, 6926 Melrose Avenue, Hollywood, California, 91638.

The Industrial Atom, 12½ minutes, 16 mm., sound, black and white.

PHYSICS FOR ELECTRONICS II (Mechanics and Heat)

Hours Required

Class, 3; Laboratory, 3.

Course Description

The aim of this course is not only to convey a knowledge of facts and fundamental theories but also to provide training in the ability to apply such knowledge to the solution of real problems. Mechanics and basic mechanical systems are emphasized since many modern electrical and electronic devices are electromechanical combinations. The mechanics of fluids and the elements of heat are introduced to broaden the base of the student's understanding of physical phenomena he will encounter as an employed electronic technician.

The subject matter should be presented in a way which shows the similarity of processes, conditions, and events rather than their differences. Special attention should be given to presenting and developing concepts of resistance and capacitance (which are not applicable solely to electrical phenomena). These concepts are fundamental to the appreciation of the factors which must be present whenever there is to be an exchange of energy. All common transfers of energy involve the same three factors—some difference of potential, some period of time, and some fixed or specified amount of energy. Potential energy, mechanical energy, energy of motion, thermal energy, and electrical energy—all can be equated to and stated as one common and basic concept, and not as a series of isolated phenomena which must be developed early in the course and emphasized as working principles throughout the entire study of physics and other electronic courses.

Major Divisions

	Class Hours	*Laboratory Hours*
I. Force	3	3
II. Composition and Resolution of Velocities and Forces	3	6
III. Solution of Concurrent Forces in Equilibrium	6	3
IV. Moments; Parallel Forces	4	3
V. Non-Concurrent Forces	3	6
VI. Uniform Motion	4	3
VII. Accelerated Motion	3	3
VIII. Work and Power	3	3
IX. Energy and Momentum	2	0
X. Friction	2	3
XI. Machines	3	3
XII. Elasticity and Strength of Materials	3	3
XIII. Mechanics of Fluids	5	3
XIV. Elements of Heat	4	6

I. Force
  A. Units of Instruction
    1. Definition of force
    2. Measurement of force
    3. Tension, compression, and shear
  B. Laboratory Projects
    Investigate and describe vector quantities.

II. Composition and Resolution of Velocities and Forces
  A. Units of Instruction
    1. Parallelogram of velocities
    2. Parallelogram of forces
    3. Composition of more than two forces
    4. Resolution into rectangular components
    5. Force polygon
  B. Laboratory Projects
    1. Learn and practice adding vectors using a force table.
    2. By the force triangle and the parallelogram method solve for the resultant of two noncolinear forces.
    3. Use the force polygon method to solve for the resultant of three noncolinear forces. Set up the problem on a friction-free force table. Check the answer by the component method.

III. Solution of Concurrent Forces in Equilibrium
  A. Units of Instruction
    1. Graphical solution techniques
    2. Mathematical solution techniques
  B. Laboratory Projects
    Study concurrent forces by use of labora-

tory equipment and practice in mathematical solutions.

IV. Moments; Parallel Forces
  A. Units of Instruction
    1. Moment of force
    2. Torque
    3. Equilibrium conditions
    4. Levers
    5. Couples
    6. Center of gravity
  B. Laboratory Projects
    1. Demonstrate and investigate moments and parallel forces.
    2. Determine experimentally the center of gravity of nonregular plane sheets of material.

V. Non-Concurrent Forces
  A. Units of Instruction
    1. Conditions for equilibrium for non-concurrent forces
    2. Free bodies
  B. Laboratory Projects
    Investigate non-concurrent forces

VI. Uniform Motion
  A. Units of Instruction
    1. Speed and velocity
    2. Velocity and distance
    3. Velocity of rotation and angular velocity
    4. Gear and belt drives
  B. Laboratory Projects
    Observe and describe the motion of machine parts

VII. Accelerated Motion
  A. Units of Instruction
    1. Acceleration of rotating bodies
    2. Accelerated linear motion
    3. Falling bodies
    4. Trajectories
    5. Simple harmonic motion
  B. Laboratory Projects
    1. Predict and measure the period of a simple pendulum
    2. Illustrate and study trajectories of particles.

VIII. Work and Power
  A. Units of Instruction
    1. Work
    2. Power
    3. Dynamometers
  B. Laboratory Projects
    Perform a brake horsepower experiment.

IX. Energy and Momentum
  A. Units of Instruction
    1. Potential energy
    2. Kinetic energy
    3. Energy transformation
    4. Conservation of energy
    5. Momentum
    6. Conservation of momentum

X. Friction
  A. Units of Instruction
    1. Coefficient of friction
    2. Determination of the coefficient of friction
    3. Laws of friction
  B. Laboratory Projects
    Determine the coefficient of friction for various surface conditions.

XI. Machines
  A. Units of Instruction
    1. Friction of machinery
    2. Simple machines
    3. Efficiency of machines
  B. Laboratory Projects
    Perform experiments to determine the mechanical advantage realized from an inclined plane and a differential chain hoist.

XII. Elasticity and Strength of Materials
  A. Units of Instruction
    1. Elasticity
    2. Shear
    3. Effects of temperature on the strength of materials
    4. Stress in beams
    5. Location of the neutral axis
    6. Torsion
  B. Laboratory Projects
    Verify Hooke's law by experimental means.

XIII. Mechanics of Fluids
  A. Units of Instruction
    1. Liquids and gases
    2. Density, specific gravity, and pressure
    3. Transmission of applied pressure through fluids
    4. Buoyancy of bodies
    5. Flow from an orifice
    6. Flow in pipes
    7. Gases

B. Laboratory Projects
   Determine the volume of several solid objects using Archimedes' Principles.

XIV. Elements of Heat
- A. Units of Instruction
  1. Temperature
  2. Expansion and contraction
  3. Quantity of heat
  4. Specific heat
  5. The heat equation
  6. Latent heat
  7. Heat transfer
- B. Laboratory Projects
  1. Determine the coefficient of linear expansion of a rod.
  2. Verify Boyle's law.
  3. Determine the specific heat of several solids.

Texts and References

BEISER. *The Mainstream of Physics*
BLACKWOOD, *and others*. *General Physics*
HARRIS *and* HEMERLING. *Introductory Applied Physics*
JAMESON *and* BANKS. *Elementary Practical Mechanics*
OREAR. *Fundamental Physics*
RESNICK *and* HALLIDAY. *Physics for Students of Science and Engineering*, Part I
SEMAT. *Fundamentals of Physics*
SHORTLEY *and* WILLIAMS. *Principles of College Physics*, Vol. I
THORNING. *General Physics and Sound*
WEBER, WHITE, *and* MANNING. *Physics for Science and Engineering*

Visual Aids

Coronet International Films, Coronet Building, Chicago, Illinois 60604

Velocity And Acceleration, 13½ minutes, 16 mm., sound, black and white: $75.00, color: $150.00. Defines motion and explains and demonstrates the concepts of velocity and acceleration. Shows the difference between speed and velocity, the careful coordination of live scenes and animation, and illustrates both positive and negative acceleration due to the force of gravity. Tells how the concepts of velocity and acceleration are useful for describing precisely the motion of all bodies in motion.

Encyclopaedia Brittanica Films, Inc., 1150 Wilmette Avenue, Wilmette, Illinois 60091.

Heat—Its Nature and Transfer, 11 minutes, 16 mm., sound, black and white: $60.00, rent: $2.50 Animation presents the nature of heat and some of the principal ways in which heat is transferred. Shows practical applications of heat in home and industry. Deals with such characteristics of heat as conduction, convection, and radiation, and develops the concept of insulation.

International Film Bureau, Inc., 332 South Michigan Avenue, Chicago, Illinois 60604.

Understanding Matter And Energy, 18 minutes, 16 mm, sound, color: $185.00, rent: $9.00. Explains the three forms of matter—liquid, solid and gaseous—and illustrates different forms of energy. Animation clarifies the molecular action of the three forms of matter and makes clear how this action determines the basic appearance of a substance. Concludes with examples of chemical, mechanical, heat, light, electrical, radiant and atomic energy.

Auxiliary and Supporting Technical Courses

CIRCUIT ANALYSIS—AC and DC

Hours Required

Class, 3; Laboratory, 6.

Course Description

This course in circuit analysis is a continuation of *Applied Physics for Electronics I* (Electricity). The characteristics of the fundamental circuit elements employed in AC networks are determined. Network theorems for both DC and AC circuits are presented, then coupled circuits are studied. The course continues with introductory work on analyzing non-sinusoidal waveshapes using mathematical techniques introduced in *Technical Mathematics II* (Applied calculus), taught concurrently. An introduction to polyphase circuits terminates the course. The techniques and understanding gained in this course will enable the student to analyze the nature and operation of complex circuits he will encounter throughout the remainder of this curriculum.

Major Divisions

	Class Hours	*Laboratory Hours*
I. Resistance, Inductance and Capacitance	3	12
II. Network Theorems	9	12
III. Series and Parallel AC Circuits	6	12
IV. Series and Parallel Resonant Circuits	6	12
V. A-C Network Theorems	6	12
VI. Coupled Circuits	9	12
VII. Nonsinusoidal Voltages and Currents	4	12
VIII. Polyphase Circuits	5	12

I. Resistance, Inductance, and Capacitance in AC Circuits
  A. Units of Instruction
    1. Pure resistance
    2. Pure inductance
    3. Pure capacitance
  B. Laboratory Projects
    1. Learn to solve simple vector problems (using the slide rule).
    2. Measure AC power in resistive circuits.
    3. Study and interpret the effects of inductive and capacitive reactance.

II. Network Theorems
  A. Units of Instruction
    1. Kirchhoff's law
    2. The superposition theorem
    3. Thevenin's theorem
    4. Norton's theorem
    5. Delta-Wye and Wye-Delta transformations
  B. Laboratory Projects
    1. Make an analysis of multiple source networks using loop equations.
    2. Make an analysis of multiple source networks using superposition theorem.
    3. Make an analysis of multiple source networks using Norton's theorem.
    4. Illustrate and study a Delta-Wye transformation.

III. Series and Parallel AC Circuits
  A. Units of Instruction
    1. Impedance and admittance
    2. The series AC circuit
    3. The parallel AC circuit
    4. The series-parallel AC circuit
    5. Power in AC circuits
  B. Laboratory Projects
    1. Plot and study the characteristics of the impedance of series R-C circuits.
    2. Plot and study the characteristics of the impedance of series R-L circuits.
    3. Plot and study the characteristics of the impedance of parallel R-C circuits.
    4. Plot and study the characteristics of the impedance of parallel R-L circuits.
    5. Plot and study the characteristics of series and parallel complex impedances.
    6. Investigate the frequency response of R-C and R-L circuits.
    7. A study of power factor measurement and correction should be performed by the students.

IV. Series and Parallel Resonant Circuits

- A. Units of Instruction
  1. Series resonance
  2. Energy storage in a resonant circuit
  3. Bandwidth
  4. Parallel Resonance
- B. Laboratory Projects
  1. Investigate the impedance of series R-L-C circuits.
  2. Investigate the relationship between voltage and current in series resonant circuits.
  3. Measure the frequency response of series tuned circuits.
  4. Investigate the impedance of parallel R-L-C circuits.
  5. Investigate resonance and frequency response of parallel tuned circuits.
  6. Learn to predict the frequency characteristics of high pass filter networks, low pass filter networks, band pass filter networks, and band stop filter networks.

V. A-C Network Theorems

- A. Units of Instruction
  1. Kirchhoff's law
  2. Superposition theorem
  3. Thevenin's theorem
  4. Norton's theorem
  5. Application to AC bridge circuits
- B. Laboratory Projects

  Analyze several AC networks with multiple sources using loop equations and the superposition theorem.

VI. Coupled Circuits

- A. Units of Instruction
  1. The general four-terminal network
  2. Transformers
  3. Analysis of closely coupled transformers
  4. Analysis of loosely coupled transformers
  5. Frequency response of iron-core transformers
  6. Maximum power transfer theorem
  7. Impedance transformation
- B. Laboratory Projects
  1. Determine a transformer's voltage and current ratio.
  2. Determine a transformer's mutual inductance.
  3. Investigate the reflected impedance of a transformer.

VII. Nonsinusoidal Voltages and Currents

- A. Units of Instruction
  1. Symmetrical and asymmetrical waves
  2. Harmonic content of nonsinusoidal waves
  3. The effective value of a nonsinusoidal voltage or current
  4. AC circuit analysis with nonsinusoidal waves
- B. Laboratory Projects

  Analyze a complex wave shape using Fourier techniques.

VIII. Polyphase Circuits

- A. Units of Instruction
  1. The generation of polyphase voltages
  2. Two-phase circuits
  3. Three-phase Wye systems
  4. Three-phase Delta systems
  5. Power in balanced three-phase systems
- B. Laboratory Projects
  1. Perform an impedance network conversion (Delta-Wye).
  2. Measure voltage and current in several different three-phase circuits.
  3. Determine the power in a balanced three-phase load.
  4. Learn and practice the use of the two-wattmeter method of power measurement.

Texts and References

ANGUS. *Electrical Engineering Fundamentals*
CARTER. *Introduction to Electrical Circuit Analysis*
CUTLER. *Electronic Circuit Analysis*
GILLIE. *Electrical Principles of Electronics*
JACKSON. *Introduction to Electric Circuits*
LURCH. *Electric Circuits*
MORECOCK. *Alternating-Current Circuits*
OPPENHEIMER *and* BORCHES. *Direct and Alternating Currents*

Visual Aids

DuArt Film Laboratories Inc., 245 West 55th Street, New York, N.Y. 10019.

Basic Electricity: AC Parallel Circuits, 5 minutes, 16 mm., sound, black and white. Produced for U.S. Department of the Navy. Order No. MN 8018-d. Summary: Shows the elements of an AC parallel circuit, examines the effects of current, and shows what the generator sees in the following circuits: LC parallel circuit, where X_l exceeds X_c; and LCR parallel circuits, where X_c exceeds X_l; and an LCR parallel circuit, where X_c equals X_l. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360

Basic Electricity: AC Series Circuits, 4 minutes, 16 mm, sound, black and white. Produced for U.S. Department of the Navy. Order No. MN 8018-c. Summary: Shows the elements of an AC series circuit; demonstrates, by sine waves and circuits, the effects upon and phase relationship between current and voltage. Using an LCR circuit, examines the effects of voltage and shows what the generator sees when X_l exceeds X_c, and when X_c exceeds X_l. Demonstrates also a series resonant circuit using an LCR circuit where X_c and X_l are equal. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360

Basic Electricity: Capacitance In AC Circuits, 5 minutes, 16 mm, sound, black and white. Produced for U.S. Department of the Navy. Order No. MN 8018-b. Summary: Defines capacitance and demonstrates how a capacitor works; explains capacitance reactance and its effects in an AC circuit; the factors that affect capacitative reactance and phase angle; discusses the physical factors that affect capacitance; and the effect of capacitance in an AC circuit. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360

Basic Electricity: Inductance In AC Circuits, 7 minutes, 16 mm, sound, black and white. Produced for U.S. Department of the Navy. Order No. MN 8018-a. Summary: Defines inductance and explains its cause and effect in an AC circuit. Illustrates inductive reactance, the factors that affect inductive reactance in an AC circuit, and the phase relationship between current and voltage as a result of the presence of inductance in the circuit. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360.

Single Phase And Polyphase Circuits, 17 minutes, 16 mm, sound, black and white. Produced for U.S. Office of Education, made by Ray-Bell Films. (Electrical work series. Electrical machinery, no. 1.) Order No. OE 383. Supplemented by filmstrip with same title. With instructor's manual. Summary: Explains a single-phase synchronous generator, the use of sine curves to illustrate flow changes, a two-phase system and three-phase system, and ways of simplifying wiring. May be borrowed from the U.S. Department of the Navy, Washington, D.C. 20360.

TECHNICAL REPORTING

Hours Required

Class, 2; Laboratory, 0

Course Description

A natural and vital extension of *Communication Skills* intended to help the student achieve greater facility in his use of the language, both spoken and written. Using the basic skills previously acquired, the student is introduced to the practical aspects of preparing reports and communicating within groups. The use of graphs, charts, sketches, diagrams, and drawings to present ideas and significant points is an important part of this course.

Emphasis is placed upon techniques for collecting and presenting scientific data by means of informal and formal reports and special types of technical papers. Forms and procedures for technical reports are studied, and a pattern is established for all forms to be submitted in this and other courses.

Much of the subject matter for this course may be necessary reports written for technical courses. The subject matter taught in this course should be closely coordinated with that of the course studied concurrently, *Drawing, Sketching and Diagramming.*

Major Divisions

		Class Hours
I.	Reporting	3
II.	Writing Technical Reports	12
III.	Illustrating Technical Reports	4
IV.	The Research Paper	3
V.	Oral Reporting	4
VI.	Group Communication and Participation	6

I. Reporting

Units of Instruction

1. Nature and types of reports
2. Objective reporting
3. The problem concept
4. The scientific method
   - a. Meaning of the method
   - b. Characteristics of the scientific method
   - c. Essentials of scientific style
   - d. Importance of accuracy and intellectual honesty in observation and recording
   - e. Legal importance of recorded data and log books
5. The techniques of exposition
   - a. Definitions
   - b. Progression
   - c. Elements of style
   - d. Analysis of examples
   - e. Methods of slanting a report
6. Critical evaluation of a report

II. Writing Technical Reports

Units of Instruction

1. Characteristics of technical reports
2. Report functions
3. Informal reports
   - a. Short-form reports
     - (1) Memorandum reports
     - (2) Business letter reports
     - (3) Progress reports
     - (4) Outline reports
4. The formal report
   - a. Arrangement
     - (1) Cover and title page
     - (2) Table of contents
     - (3) Summary of abstracts
     - (4) Body of the report
     - (5) Bibliography and appendix
     - (6) Graphs, drawings, or other illustrations
   - b. Preparation
     - (1) Collecting, selecting, and arranging material
     - (2) Writing and revising the report
5. Special types of papers
   - a. The abstract
   - b. Process explanations
   - c. The case history
   - d. The book review

III. Illustrating Technical Reports

Units of Instruction

1. Illustrations as aids to brevity and clarity
2. Use of technical sketching and drawings
3. Use of pictorial drawings and sketches
4. Use of diagrammatic representation
   - a. Electrical diagrams and symbols

    b. Process flow diagrams
    c. Instrumentation diagrams
    d. Bar charts, pie diagrams and similar presentation of data
5. Graphical presentation of data
    a. Types of graph paper
    b. Choice of scale for graphs
    c. Points and lines
    d. Use of data from graphs
6. Use of photographs
7. Selection of appropriate illustrations
    a. Availability
    b. Cost of preparation
    c. Maximum brevity and clarity of presentation

IV. The Research Paper

Units of Instruction

1. Subject and purpose
2. Source materials
    a. Bibliographical tools
    b. Periodical indexes
    c. The library
3. Organizing the paper
    a. A working bibliography
    b. Notes and the outline
    c. The rough draft
    d. Quoting and footnoting
    e. The final paper
4. Oral and written presentation of the paper

V. Oral Reporting

Units of Instruction

1. Organization of material for effective presentation
2. Formal and informal reports
3. Use of notes
4. Use of slides, exhibits
5. Proper use of the voice
6. Elimination of objectionable mannerisms
7. Introduction

VI. Group Communication and Participation

Units of Instruction

1. The problem-solving approach
    a. Stating and analyzing the problem
    b. Proposing solutions
    c. Selecting and implementing a solution
2. Participating in group communication
    a. The chairman—duties and qualifications
    b. Rules of order
    c. The panel discussion and symposium
    d. Group investigation

Texts and References

BAIRD *and* KNOWER. *Essentials of General Speech*

——— *and* ———. *General Speech: An Introduction*

BORDEAUX. *How to Talk More Effectively*

CROUCH *and* ZETLER. *Guide to Technical Writing*

DEAN *and* BRYSON. *Effective Communication*

HARWELL. *Technical Communications*

HICKS. *Successful Technical Writing*

KEGAL *and* STEVENS. *Communication: Principles and Practices*

MARDER. *The Craft of Technical Writing*

MCCRORIE. *The Perceptive Writer, Reader, and Speaker*

PERRIN *and* SMITH. *Handbook of Current English*

RHODES. *Technical Report Writing*

ROGET. *New Roget's Thesaurus of the English Language in Dictionary Form*

SCHUTTE *and* STEINBERG. *Communication in Business and Industry*

SOUTHER. *Technical Report Writing*

THOMPSON. *Fundamentals of Communication*

WARRINER *and* GRIFFITH. *English Grammar and Composition: A Complete Handbook*

WITTY. *How to Become a Better Reader*

YOUNG *and* SYMONIK. *Practical English, Introduction to Composition*

ZETLER *and* CROUCH. *Successful Communication in Science and Industry*

Visual Aids

McMurry-Gold Productions, 139 South Beverly Drive, Beverly Hills, California 91603

Person To Person Communication. 13 minutes, 16 mm, black and white, sound

National Educational Television Film Service, Audio-Visual Center, Indiana University, Bloomington, Ind. 47405.

Experience As Give And Take. 29 minutes, 16 mm, black and white, sound. Produced by Hayakawa. (Language in Action Series)

Talking Ourselves Into Trouble. 29 minutes, 16 mm, black and white, sound. Produced by Hayakawa. (Language in Action Series)

Words That Don't Inform. 29 minutes, 16 mm, sound. Produced by Hayakawa. (Language in Action Series)

National Safety Council, 425 N. Michigan Ave., Chicago, Ill. 60601.

It's An Order. 12 minutes, 16 mm, black and white, sound

DRAWING, SKETCHING, AND DIAGRAMMING

Hours Required

Class, 0; Laboratory, 3.

Course Description

This course emphasizes the means for presenting information effectively, using drawings, prints, sketches, graphs, charts and diagrams. The use of graphs, mathematical relationships, drawings, and diagrams to present significant points clearly is an important portion of the course. Engineering and development work usually employ to a considerable degree sketches and free-hand drawings. A technician should be able to make suitable illustrative rough sketches or drawings to provide adequate information for making a part or to describe some machine, component, system, or cuircuit.

The drawing and illustrative skills acquired in this course should be employed extensively in the concurrently studied *Technical Reporting* course and should be reflected in the reports written for technical courses throughout the remainder of the curriculum. The use of drawing and sketching aids and techniques should take precedence over precision and quality of lines and lettering in the teaching of this course. Neatness must be emphasized, but the objective of the course is to develop illustrative and graphic communication skills rather than technical drafting proficiency.

It is expected that this course will be taught in a drafting room equipped with a blackboard, where the instructor will devote a part of each period to demonstrating various techniques for drawing, free hand sketching, graphing, charting and diagramming, and where the rest of the laboratory period will be used to practice the demonstrated skills and techniques.

Major Divisions

	Laboratory hours
I. Diagnostic Tests	2
II. Technical Sketching	12
III. Dimensioning Drawings	4
IV. Pictorial Drawing	9
V. Electrical and Electronic Symbols	6
VI. Sketch of Simple Electronic Installation	6
VII. Graphical Presentation of Data	9

I. Diagnostic Tests
  Unit of Instruction
    Determination of the general level of competence in the main areas of sketching, drawing, dimensioning, using symbols, and making graphs

II. Technical Sketching
  A. Units of Instruction
    1. Techniques of freehand sketching
      a. Measuring subject
      b. Blocking, drawing, and proportioning
      c. Detailing
    2. Theory of projection
      a. Isometric
      b. Oblique
      c. Sketching projections
    3. Multiview drawing
      a. Principles of multiview drawing
      b. Relationship of views
      c. Selection of views
      d. Treatment of invisible surfaces and center lines
    4. Sectional views, types and purposes
      a. Symbolic lines
      b. Half sections and broken sections
      c. Full sections
  B. Instructional Projects
    Make freehand sketches of simple electronic element parts to develop skill in estimating distances, proportions, relative sizes, and relationships.

III. Dimensioning Drawings
  A. Units of Instruction
    1. General dimensioning
      a. Size and location dimensions
      b. Fractional and decimal dimensioning
      c. Do's and don'ts of dimensioning
      d. Procedure in dimensioning
      e. Lettering for name plates, information, dimensions, and notes
    2. Formulation and placement of shop notes
      a. Purpose of notes

      - b. Shop terms of processor
      - c. How to make measurements of shop operations
    - 3. Tolerances
      - a. Purpose
      - b. Terminology
      - c. Classes of fits
  - B. Instructional Projects
    - 1. Construct freehand multiview drawings of machine parts requiring simple dimensions and shop notes.
    - 2. Construct freehand multiview drawings of more complex machine parts requiring decimal dimensioning and determining and indicating tolerances.

- IV. Pictorial Drawing
  - A. Units of Instruction
    - 1. Isometric drawing
      - a. Position of axes
      - b. Non-isometric lines
      - c. Steps in construction
      - d. 4-center method of constructing ellipses
      - e. Advantages and disadvantages
    - 2. Oblique drawing
      - a. Choice of position of axes
      - b. Steps in construction
      - c. Methods of reducing distortion
      - d. Advantages and disadvantages
    - 3. Perspective
      - a. General principles
      - b. One-point
      - c. Two-point
      - d. Advantages and disadvantages
    - 4. Shading
      - a. Shade lines
      - b. Surface shading with lines
      - c. Smudge shading
      - d. Stippling
  - B. Instructional Projects
    - 1. Make an isometric drawing of a servomechanism or some similar piece of equipment. Stress correct projection and position of axes. Require suitable shading.
    - 2. Make an oblique drawing of a small control panel. Use either one- or two-point perspective.

- V. Electrical and Electronic Symbols
  - A. Units of Instruction
    - 1. Industrial symbols
      - a. Electronic
      - b. Electrical
      - c. Architectural
      - d. Relay
    - 2. Schematic diagrams
      - a. Schematic layouts
      - b. One-line diagrams
    - 3. Wiring diagrams
      - a. Electrical control panel
      - b. Complex electronic circuit system
      - c. Communication circuits
      - d. Data transmission
  - B. Instructional Projects
    - 1. Study and learn the symbols commonly used to represent electrical and electronic components and assemblies. Apply them in simple schematic arrangements.
    - 2. Construct a simple one-line diagram of a relatively simple electronic control system.
    - 3. Make a schematic diagram of the same installation.

- VI. Sketch of Simple Electronic Installation
  - A. Units of Instruction
    - 1. Preferred ways of presenting electronic installations
      - a. Single component or element
      - b. Multiple components or elements
    - 2. Other types of electrical devices
      - a. Single component or element
      - b. Multiple components or elements
  - B. Instructional Projects
    - 1. Sketch the apparatus and wiring required for the calibration of an ohmmeter or some other instrument. Include a wiring diagram showing necessary wiring, components, wire sizes, and component capacities.
    - 2. Sketch the instruments required for an electronic control console or panel.

- VII. Graphical Presentation of Data
  - A. Units of Instruction
    - 1. Types of graph paper
      - a. Rectangular
        - (1) Inch scale
        - (2) Centimeter scale
      - b. Semi-log
      - c. Log-log
      - d. Double scales
    - 3. Points and lines
      - a. Point plotting
      - b. Line identification
      - c. Name plate

4. Data from graphs
    a. Proper data from graph and calculations
    b. Error points
5. Construction of nomographs

B. Instructional Projects
1. Plot and obtain information from the following types of graphs:
    a. Rectangular
    b. Polar
    c. Semi-log
    d. Log-log
    e. Tri-linear
2. Construct a simple nomograph.

Texts and References

AMERICAN STANDARD ASSOCIATION. *Drafting Manual.* ASA-Y14

———. *Graphic Symbols.* ASA-Y32

BAER. *Electrical and Electronics Drawing*

FRENCH *and* VIERCK. *Fundamentals of Engineering Drawing*

GRACHINO. *Drafting and Graphics*

HOELSCHER *and* SPRINGER. *Engineering Drawing and Geometry*

INSTRUMENT SOCIETY OF AMERICA. *Recommended Practice—Instrumentation Flow Plan Symbols,* ISA-RP5.1

LEVEN. *Graphics with an Introduction to Conceptual Design*

Visual Aids

The Pennsylvania State University, University Park, Penn. 16802.

According To Plan: Introduction To Engineering Drawing, 9 minutes, 16 mm, black and white, sound

Drawing And The Shop, 15 minutes, 16 mm, black and white, sound

Freehand Drafting, 15 minutes, 16 mm, black and white, silent

Shop Drawings, 22 minutes, 16 mm, black and white, sound

General Courses

COMMUNICATION SKILLS

Hours Required

Class, 3; Laboratory, 0.

Course Description

This course places emphasis throughout on exercises in reading, writing, speaking, and listening. Analysis is made of each student's strengths and weaknesses. The pattern of instruction is geared principally to helping students improve skills in areas where common weaknesses are found. The time allotments for the various elements within major divisions will depend upon the background of the class.

A brief consideration of technical reporting is included early in the course because of its importance in the orientation of the technician to his development and use of communication skills.

Major Divisions

	Class hours
I. Communication and the Technical Specialist	2
II. Sentence Structure	6
III. Using Resource Materials	4
IV. Written Expression	20
V. Talking and Listening	10
VI. Improving Reading Efficiency	6

I. Communication and the Technical Specialist

Units of Instruction

1. Why the technical specialist must be proficient in the art of communication
2. Why written communication is an essential skill
   a. Statements of facts
   b. Expression of ideas
   c. Technical reporting
      (1) Formal
      (2) Informal
   d. Use of graphics to illustrate written communications
3. Why oral communication is an essential skill
   a. Person to person expression of ideas and thoughts
   b. Verbal reporting
4. Diagnostic tests

II. Sentence Structure

Units of Instruction

1. Review of basic parts of speech
2. What makes complete sentences
3. Use and placement of modifiers, phrases, and clauses
4. Sentence conciseness
5. Exercises in sentence structure

III. Using Resource Materials

Units of Instruction

1. Orientation in use of school library
   a. Location of reference materials, *Readers Guide*, etc.
   b. Mechanics for effective use
   c. Dewey Decimal System
2. Dictionaries
   a. Types of dictionaries
   b. How to use dictionaries
   c. Diacritical marks and accent marks
3. Other reference sources
   a. Technical manuals and pamphlets
   b. Bibliographies
   c. Periodicals
   d. *Industrial Arts Index*
4. Exercises in use of resource materials
   a. *Readers Guide*
   b. Atlas
   c. Encyclopedia
   d. Other

IV. Written Expression (emphasis on student exercises)

Units of Instruction

1. Diagnostic test
2. Paragraphs
   a. Development
   b. Topic sentence
   c. Unity of coherence
3. Types of expression
   a. Inductive and deductive reasoning

   b. Figures of speech
   c. Analogies
   d. Syllogisms
   e. Cause and effect
   f. Other
4. Written exercises in paragraphing
5. Descriptive reporting
   a. Organization and planning
   b. Emphasis on sequence, continuity, and delimitation to pertinent data of information
6. Letter writing
   a. Business letters
   b. Personal letters
7. Mechanics
   a. Capitalization
   b. Punctuation—when to use:
      (1) Period, question mark, and exclamation point
      (2) Comma
      (3) Semicolon
      (4) Colon
      (5) Dash
      (6) Parentheses
      (7) Apostrophe
   c. Spelling
      (1) Word division—syllabification
      (2) Prefixes and suffixes
      (3) Word analysis and meaning—context clues, phonetics, etc.
8. Exercises in mechanics of written expression

V. Talking and Listening (emphasis on student exercises)

Units of Instruction

1. Diagnostic testing
2. Organization of topics or subject
3. Directness in speaking
4. Gesticulation and use of objects to illustrate
5. Conversation courtesies
6. Listening faults
7. Taking notes
8. Understanding words through context clues
9. Exercises in talking and listening

VI. Improving Reading Efficiency

Units of Instruction

1. Diagnostic test
2. Reading habits
   a. Correct reading posture
   b. Light sources and intensity
   c. Developing proper eye span and movement
   d. Scanning
   e. Topic sentence reading
3. Footnotes, index, bibliography, cross references, etc.
4. Techniques of summary
   a. Outline
   b. Digest or brief
   c. Critique
5. Exercise in reading improvement
   a. Reading for speed
   b. Reading for comprehension

Texts and References

Baird *and* Knower. *Essentials of General Speech*
——— *and* ———. *General Speech, An Introduction*
Beardsley. *Thinking Straight*
Bordeaux. *How to Talk More Effectively*
Buckler *and* McAvory. *American College Handbook of English Fundamentals*
Crouch *and* Zetler. *Guide to Technical Writing*
Dean *and* Bryson. *Effective Communication*
DeVitis *and* Warner. *Words in Context: A Vocabulary Builder*
Gerber. *The Writer's Resource Book*
Harwell. *Technical Communication*
Kegel *and* Stevens. *Communication: Principles and Practices*
Lee. *Language Habits in Human Affairs*
Marder. *The Craft of Technical Writing*
McCrorie. *The Perceptive Writer, Reader, and Speaker*
Perrin *and* Smith. *Handbook of Current English*
Roget. *New Roget's Thesaurus of the English Language in Dictionary Form*
Schutte *and* Steinberg. *Communication in Business and Industry*
Stewart *and others*. *Business English and Communication*
Strunk *and* White. *The Elements of Style*
Thompson. *Fundamentals of Communication*
Tracy *and* Jennings. *Handbook for Technical Writers*
Warriner *and* Griffith. *English Grammar and Composition: A Complete Handbook*
Witty. *How to Become a Better Reader*
Young *and* Symonik. *Practical English, Introduction to Composition*
Zetler *and* Crouch. *Successful Communication in Science and Industry*

Visual Aids

Coronet Films, Inc., Coronet Building, Chicago, Illinois, 60604.

Improve Your Puncuation, 11 minutes, 16 mm, sound, black and white or color. Summary Guides teacher and class in work with puncuation trouble spots, covering the chief uses of the comma, the semi-colon, the colon, the question mark, and the quotation mark. Stresses the use of punctuation as a means of clarifying written communication.

National Education Television Film Service, Audio-Visual Center, Indiana University, Bloomington, Indiana 47405

The Definition Of Language, 29 minutes, 16 mm, sound. Produced by Henry Lee Smith. (Language in Linguistics Series)

Dialects, 29 minutes, 16 mm, black and white, sound. Produced by Henry Lee Smith. (Language in Linguistics Series)

How To Say What You Mean, 29 minutes, 16 mm, black and white, sound. Produced by S. I. Hayakawa. (Language in Action Series)

Language And Writing, 29 minutes, 16 mm, black and white, sound. Produced by Henry Lee Smith. (Language in Linguistics Series)

The Task Of The Listener, 29 minutes, 16 mm, black and white, sound. Produced by S. I. Hayakawa. (Language in Action Series)

Where Is The Meaning?, 29 minutes, 16 mm, black and white, sound. Produced by S. I. Hayakawa. (Language in Action Series)

DuArt Film Laboratories Inc., 245 West 55th Street, New York, N.Y. 10019

Effective Writing, 19 minutes, 16 mm, sound, black and white. U.S. Department of the Air Force. Order No. TF 1-5072. Summary: Describes communication from the concrete symbols of the cave man to the prolixities and ambiguities of some current Government writing. Explains the rules for organizing material and gives various examples of ineffective writing with recommendations for improvement. May be borrowed from U.S. Air Force, Film Library Center, 8900 South Broadway, St. Louis, Mo. 63125.

Practical English Usage, Lecture 1: The Tools of Language, 30 minutes, 16 mm, sound, black and white. U.S. Department of Defense. Summary: Discusses parts of speech—nouns, pronouns, verbs, adjectives, adverbs, conjunctions, prepositions, and interjections—and describes the use of words as different parts of speech.

Practical English Usage 1, Lecture 10: Writing Clear Sentences: Making Words Agree, 30 minutes, 16 mm, sound, black and white. U.S. Department of Defense. Summary: Explains agreement of subject and verb, of pronoun and antecedent, and explains the need for agreement in special cases.

Practical English Usage I, Lecture 16: Dressing Up Sentences; Vocabulary, 30 minutes, 16 mm, sound, black and white. U.S. Department of Defense. Summary: Explains how to avoid trite expressions and mixed figures of speech in a sentence and discusses the use of idiomatic and appropriate words.

GENERAL AND INDUSTRIAL ECONOMICS

Hours Required

Class, 3; Laboratory, 0

Course Description

A study of economics designed to impart a basic understanding of the principles of economics and their implications; to develop the ability to follow an informed personal finance program; to aid in the development of intelligent consumption; and to provide an understanding of the underlying relationship of cost control to success in industrial enterprise. The programs or problems worked upon by any technician in either research or production ultimately must be measured by a cost analysis. Awareness of this fact and a knowledge of elementary economics prepare the student for the cost-concious environment of his future employment. It is suggested that instruction in this course be based on this pragmatic approach and that students be encouraged to study examples from industry as they learn about industrial cost analysis, competition, creation of demand, economic production, and related aspects of applied economics.

Major Divisions

	Class hours
I. Introduction	2
II. Economic Forces and Indicators	3
III. Natural Resources—The Basis of Production	3
IV. Capital and Labor	3
V. Business Enterprise	7
VI. Factors of Industrial Production Cost	8
VII. Price, Competition, and Monopoly	5
VIII. Distribution of Income	2
IX. Personal Income Management	2
X. Insurance, Personal Investments, and Social Security	3
XI. Money and Banking	3
XII. Government Expenditures, Federal and Local	3
XIII. Fluctuations in Production, Employment, and Income	2
XIV. The United States Economy in Perspective	2

I. Introduction
    Basic economic concepts

II. Economic Forces and Indicators
1. Economics defined
2. Modern specialization
3. Increasing production and consumption
4. Measures of economic activity
    a. Gross national product
    b. National income
    c. Disposable personal income
    d. Industrial production
    e. Employment and unemployment

III. Natural Resources—The Basis of Production
1. Utilization and conservation of resources
2. Renewable resources
3. Non-renewable resources
4. Future sources

IV. Capital and Labor
1. Tools (Capital)
    a. The importance of saving and investment
    b. The necessity for markets
2. Large-scale enterprise
3. Labor
    a. Population characteristics
    b. Vocational choice
    c. General education
    d. Special training
    e. Management's role in maintaining labor supply

V. Business Enterprise
1. Forms of business enterprise
    a. Individual proprietorship
    b. Partnership
    c. Corporation
2. Types of corporate securities
    a. Common stocks
    b. Preferred stocks
    c. Bonds
3. Mechanics of financing business
4. Plant organization and management

VI. Factors of Industrial Production Cost
  1. Buildings and equipment
    a. Initial cost and financing
    b. Repair and maintenance costs
    c. Depreciation and obsolescence costs
  2. Materials
    a. Initial cost and inventory value
    b. Handling and storage costs
  3. Processing and production
    a. Methods of cost analysis
    b. Cost of labor
    c. Cost of supervision and process control
    d. Effect of losses in percentage of original product compared to finished product (yield)
  4. Packaging and shipping
  5. Overhead costs
  6. Taxes
  7. Cost of selling
  8. Process analysis, a means to lower costs
  9. Profitability and business survival

VII. Price, Competition, and Monopoly
  1. Function of prices
  2. Price determination
    a. Competitive cost of product
    b. Demand
    c. Supply
    d. Interactions between supply and demand
  3. Competition, benefits, and consequences
    a. Monopoly and oligopoly
    b. Forces that modify and reduce competition
    c. History of government regulation of competition
  4. How competitive is our economy?

VIII. Distribution of Income
  1. Increasing real incomes
  2. Marginal productivity
  3. Supply in relation to demand
  4. Incomes resulting from production
    a. Wages
    b. Interest
    c. Rents
    d. Profits
  5. Income distribution today

IX. Personal Income Management
  1. Consumption—the core of economics
  2. Economizing defined
  3. Personal and family budgeting
  4. Analytical buying
    a. Applying quality standards
    b. Consumer's research and similar aids
  5. The use of credit
  6. Housing—own or rent

X. Insurance, Personal Investments, and Social Security
  1. Insurance defined
  2. Life insurance
    a. Group, industrial, and ordinary life policies
    b. Type of policies—their advantages and disadvantages
  3. Casualty insurance
  4. Investments
    a. Savings accounts and Government bonds
    b. Corporation bonds
    c. Corporation stocks
    d. Annuities
    e. Pension plans
  5. Social Security
    a. Old-Age and survivors insurance
    b. Unemployment compensation
    c. Medicare

XI. Money and Banking
  1. Functions of money
  2. The Nation's money supply
  3. Organization and operation of a bank
    a. Sources of deposits
    b. The reserve ratio
    c. Expansion of bank deposits
    d. Sources of reserves
  4. The Federal Reserve System
    a. Service functions
    b. Control of money supply
  5. Federal Deposit Insurance Corporation

XII. Government Expenditures, Federal and Local
  1. Economic effects
  2. Functions of Government
  3. Analysis of Government spending
  4. Future outlook
  5. Financing Government spending
    a. Criteria of sound taxation
    b. Tax revenues in the United States
    c. The Federal and State personal income taxes
    d. The corporate income tax

    - e. The property tax
    - f. Commodity taxes

XIII. Fluctuations in Production, Employment, and Income

  1. Changes in aggregate spending
  2. Output and employment
  3. Other factors affecting economic fluctuations
     - a. Cost-price relationships
     - b. Fluctuations in demand for durable goods
     - c. Involuntary fluctuation of supply of commodities
     - d. Economic effects of war
     - e. Inflation and deflation of currency value
     - f. Economic effects of inventions and automation
  4. Means of implementing fiscal policy
  5. Government debt
     - a. Purposes of Government borrowing
     - b. How burdensome is the debt
     - c. Problems of debt management

XIV. The United States Economy in Perspective

  1. Recent economic changes
     - a. Increased productivity and well-being
     - b. Effects of war and depression
     - c. New products and industries
     - d. Increase in governmental controls
  2. Present economic problems of U.S. economy
     - a. The world market—a community of nations
     - b. International cooperation
     - c. Maintenance of prosperity and progress

    - d. Economic freedom and security
  3. Communism: Nature and control by Soviet State
  4. Fascism
  5. British socialism
  6. Problems common to all economic systems
  7. Special economic problems of the United States

Texts and References

BLODGETT. *Comparative Economic Systems*
Business Week Magazine
Consumers' Report
DONALDSON *and* PFAHL. *Personal Finance*
DUNLOP. *Automation and Technological Change*
DYE. *Economics: Principles, Problems, Perspectives*
EDWARDS. *The Nation's Economic Objectives*
GORDON. *Economics for Consumers*
KATONA. *The Mass Consumption Society*
POND. *Essential Economics: An Introduction*
REYNOLDS. *Economics: A General Introduction*
SAMUELSON. *Economics: An Introductory Analysis*
SCHULTZ. *The Economic Value of Education*

Visual Aids

McGraw-Hill Book Co., Inc., 330 West 42nd Street, New York, N.Y. 10036.

Basic Economic Concepts. 35 mm., filmstrip—set of 4 filmstrips, black and white. Average 40 frames each.

Business Cycles And Fiscal Policy. 35 mm., filmstrip, black and white.

Money, Prices, And Interest. 35 mm., filmstrip, black and white.

Savings And Investment. 35 mm., filmstrip, black and white.

Supply And Demand. 35 mm., filmstrip, black and white.

INDUSTRIAL ORGANIZATIONS AND INSTITUTIONS

Hours Required

Class, 3; Laboratory, 0

Course Description

A description and analysis of the roles of labor and management in the economy of the United States are presented. Approximately half of the classroom time is devoted to labor-management relations, including the evolution and growth of the American labor movement and the development and structure of American business management. A study is made of the legal framework within which labor-management relations are conducted and the responsibilities of each in a democratic system of government. The second half of the course pertains to labor-economics as applied to the forces affecting labor supply and demand, problems of unemployment and wage determination on the national, plant, and individual levels. Emphasis centers upon current aspects of industrial society with historical references intended only as background.

Major Divisions

		Class hours
I.	Labor in an Industrial World	9
II.	Management in an Industrial Society	9
III.	The Collective Bargaining Process	12
IV.	Dynamics of the Labor Market	8
V.	Wage Determination	7
VI.	The Balance Sheet of Labor-Management Relations	3

I. Labor in an Industrial World
   1. The nature and scope of the Industrial Revolution
      a. The factory system
      b. Occupational trends
      c. Mechanisms of adjustment
   2. The evolution of American labor unions
      a. Nature of early unions: basic system of craft unions
      b. Organizations by unions for solving problems
      c. Emergence of business unionism
      d. The changing role of government
   3. Structure and objectives of American unions
      a. Objectives in collective bargaining
      b. Political objectives and tactics
      c. Structure of craft and industrial unions
      d. Movement toward unity—the AFL-CIO merger

II. Management in an Industrial Society
   1. The rise of big business
      a. Economic factors
      b. Dominance of the corporate firm
      c. Government, public policy, and big business
   2. The Managerial Revolution
      a. Changing patterns of ownership and management
      b. Scientific management
      c. Twentieth century trends
   3. Structure and objectives of American Industry
      a. Production for profit: an Affluent Society
      b. Structure of industry—organizational forms
      c. Ethics in a competitive economy

III. The Collective Bargaining Process
   1. Legal framework
      a. Common law provisions
      b. The growth of laws
         (1) The antitrust laws; aid to emergence of collective bargaining
         (2) The Addamson and LaFollette Laws
         (3) Norris-LaGuardia
         (4) Wagner Act
         (5) Taft-Hartley
         (6) Landrum-Griffin and beyond
   2. Management and collective bargaining
   3. Bargaining procedures and tactics, including conciliation and mediation process
   4. Issues in collective bargaining
      a. Security issues
      b. Working conditions
      c. Safety provisions and safety education
      d. Money matters
   5. Strikes and lockouts: tactics and prevention

6. Evaluation of collective bargaining

IV. Dynamics of the Labor Market
   1. Labor supply and the market
      a. Level and composition of the labor force
      b. Changing patterns of employment
      c. Some questions about labor supply and the market
   2. Reduction and control of unemployment
      a. Types of unemployment
      b. Proposed schemes of employment stabilization
      c. Continuing problems
   3. Labor mobility
      a. Types of labor mobility
      b. Deterrents to labor mobility
      c. Suggested programs to improve labor mobility

V. Wage Determination
   1. Wages, process, and employment
      a. Meaning of wages
      b. Wages and the productive process
      c. The problem of inflation
   2. Wages and the national income
      a. Concepts of measurement and productivity
      b. Determinants of productivity
      c. The distribution of national income
   3. Wage structures
      a. Occupational differences
      b. Geographic patterns
      c. Industry patterns
      d. Wage determination: plant level, individual wages

VI. The Balance Sheet of Labor-Management Relations
   1. The control and elimination of poverty in a modern industrial State
      a. The extent of poverty
      b. The attack on poverty
      c. Trends and portents
   2. Justice and dignity for all in an industrial democracy
      a. The worker—status and goals
      b. Management—rights and responsibilities
      c. The future of capitalistic society

Texts and References

BLOOM *and* NORTHRUP. *Economics of Labor Relations*
BOWEN. *Labor and the National Economy*
BUNTING. *The Hidden Face of Free Enterprise*
CHAMBERLIN. *The Economic Analysis of Labor Union Power*
ELLS. *The Meaning of Modern Business: An Introduction to the Philosophy of Large Corporate Enterprises*
FAULKNER. *American Economic History*
GEARY. *The Background of Business*
GITLOW. *Labor and Industrial Society*
GREGORY. *Labor and the Law*
GRIMSHAW *and* HENNESSEY. *Organizational Behavoir—Cases and Readings*
KERR *and others*. *Industrialization and Industrial Man*
LEIERSON. *American Trade Union Democracy*
LEVITAN. *Federal Manpower Policies and Programs to Combat Unemployment*
LEVITAN. *Reducing Worktime as a Means to Combat Unemployment*
MANGUM. *Wage Incentive System*
MCGREGOR. *The Human Side of Enterprise*
NATIONAL MANPOWER COUNCIL. *Government and Manpower*
PFIFFNER. *Administrative Organization*
PHELPS. *Introduction to Labor Economics*
REYNOLDS. *Labor Economics and Labor Relations*
RICHBERG. *Labor Union Monopoly, A Clear and Present Danger*
SLITCHER *and others*. *The Impact of Collective Bargaining on Management*
SULTAN. *Labor Economics*
TAFT. *Economics and Problems of Labor*
WOLFBEIN. *Employment and Unemployment in the United States*
U.S. DEPARTMENT OF LABOR. *The American Worker's Fact Book*
———. BUREAU OF LABOR STATISTICS. *Interim Revised Projections of U.S. Labor Force—1965–75.*

Visual Aids

The Brookings Institution, 1775 Massachusetts Avenue, N.W. Washington, D.C. 20036.
Big Enterprise In The Competitive System. 40 min., 16 mm., sound, color.

Coronet Films, Inc., Coronet Building, Chicago, 60604.
Labor Movement: Beginnings And Growth In America. 13½ min., 16 mm., black and white or color, sound

Encyclopaedia Britannica Films, Inc., 1150 Wilmette Ave., Wilmette, Ill. 60091
Productivity—Key To Plenty. 22 min., 16 mm., black and white, sound
Working Together. (A Case History in Labor Management Cooperation) 24 min., 16 mm., black and white, sound

McGraw-Hill Book Company, Inc., New York, N.Y. 10036
Internal Organization. 10 min., 16 mm., black and white, sound
Job Evaluation. 13 min., 16 mm., black and white, sound

Teaching Film Custodians, 25 West 43rd Street, New York, N.Y. 10036
Bargaining Collectively. 10 min., 16 mm., black and white, sound

Indiana University, Bloomington, Ind. 47405
Decision: Constitution And The Labor Union. 29 min., 16 mm., black and white, sound

FACILITIES, EQUIPMENT, AND COSTS

General Planning of Facilities

Laboratory and related classrooms, offices, and storage facilities required for teaching electronic technology do not present special or unusual conditions peculiar to the technology. Any well-constructed building with suitable utilities may be used. However, if a building is to be constructed to house an Electronic Technology program, plans should include maximum use of movable partitions and portable equipment to attain greatest flexibility and utility of space.

Figure 8.—Laboratory experiments should be designed to emphasize a single point being covered in theory class. It is better to have more experiments of this type than fewer experiments covering many complex aspects of theory.

If possible, the electronic laboratory should be on the ground floor where the receiving and dispatching of butane bottles, industrial electronic or instrumentation equipment, and materials may be most efficiently accomplished. These considerations are purely for convenience, and in no way mandatory.

Normal environmental control for electronic technology laboratories and classrooms is necessary; and in geographic areas where extremes of warm weather and high humidity prevail for any appreciable part of the year when the facilities are to be used, air conditioning has been found to be almost necessary.

A classroom near the electronic laboratory is desirable. Classrooms and laboratores should be well lighted with a recommended minimum of 50-foot candles of light at the table or desk tops. Fluorescent lighting is satisfactory.

Hot and cold water, and *fuel gas* service lines to the laboratories should be planned for the shortest length of piping consistent with laboratory arrangement. They should be hidden as far as practicable, but control points should be planned for safety, accessibility, and ease of maintenance. It is recommended that *each laboratory* have a master control panel with shut-off valves for each utility. This master control panel should have a door with lock so that utilities can be controlled at a central point.

Electrical services should provide both 110- and 220-volt single-phase electrical service for electronic laboratories. Most equipment used in the laboratory requires 110 volts; occasionally a 220-volt single-phase current is required.

In connecting electrical service to laboratory benches, it is suggested that each be connected to a separate circuit breaker, and the circuits be designed with ample capacity so that when a number of students in the laboratory are using electrical apparatus, the lines will not become overloaded. Each laboratory should have a separate master distribution control panel for electrical circuits.

When planning space requirements for an electronics technology department many factors must be considered, some of which are: the number of students; available facilities; the number of staff members to be involved; and the length of the program. These factors and many others come into play before suggestions for area allotments can be made. The following discussion has been developed for a 2-year program involving 20 to 25 beginning electronic students, 20 advanced students, and three instructors in the technical specialty courses. Students in excess of this number may be accommodated by use of multiple laboratory sections or by assigning more than two students to each laboratory group. Figure 9 is one example of total floor space arrangement for such a program. The access hall has been centrally located to permit adequate classroom or laboratory areas on both sides. The hallway has been extended only part way down the length of the major area to prevent through traffic and to allow compact room layout. Through traffic is undesirable from both a security and disturbance point of view. Compactness is desirable for convenience to students and staff.

There are many ways in which the U-shaped internal area may be divided into classrooms, laboratories, and staff facilities. Figure 10 shows another of the many possibilities for arrangement in the space shown in figure 9. For the sake of flexibility it is suggested that all internal walls be steel and glass movable partitions. Such construction permits changes to be made if they become necessary or desirable.

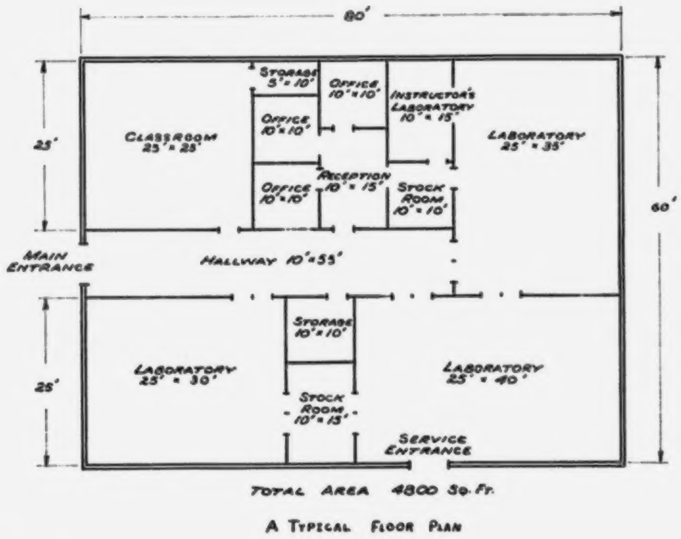
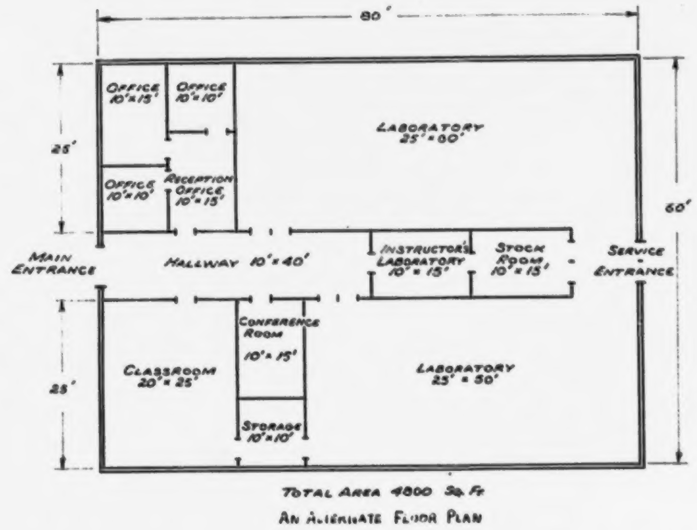

80'
25'
25'
60'
Storage 5' × 10'
Office 10' × 10'
Instructor's Laboratory 10' × 15'
Office 10' × 10'
Classroom 25' × 25'
Laboratory 25' × 35'
Reception 10' × 15'
Office 10' × 10'
Stock Room 10' × 10'
Main Entrance
Hallway 10' × 55'
Storage 10' × 10'
Laboratory 25' × 30'
Laboratory 25' × 40'
Stock Room 10' × 15'
Service Entrance
Total Area 4800 Sq. Ft.
A Typical Floor Plan

Figure 9.—One example of floor space arrangement for an electronic technology teaching facility. Figure 10.—An alternate floor plan for the space shown in Figure 9.


80'
25'
25'
60'
Office 10' × 15'
Office 10' × 10'
Laboratory 25' × 60'
Office 10' × 10'
Reception Office 10' × 15'
Main Entrance
Hallway 10' × 40'
Instructor's Laboratory 10' × 15'
Stock Room, 10' × 15'
Service Entrance
Conference Room 10' × 15'
Classroom 20' × 25'
Laboratory 25' × 50'
Storage 10' × 10'
Total Area 4800 Sq. Ft.
An Alternate Floor Plan

The floor plan should contain sufficient classroom space to accommodate the students within the department conveniently. Usually a single classroom is adequate. Normally the classroom would be equipped with student desks, chalkboard, and a screen to be used with projection equipment. The room should be well lighted with at least 50-foot candles at desk level and should be equipped to control the light to facilitate the use of visual aids. Electric outlets for the projection equipment should be provided. A storage area adjacent to the classroom should be included for storage of visual aids and demonstration equipment.

Laboratory space is probably the most important area in an electronic department. The laboratories should be planned for optimum convenience and utility for both students and instructors. Consequently, individual work benches equipped for teams of two students are preferred to long common benches for many students. Storage space for instruments and equipment usually should be adjacent to the laboratory. Doorways should be located for easy traffic flow into and out of the laboratory. Storage areas in laboratories should be located so that the instructor can readily control the movement of stock and instruments. Laboratories should be equipped with a chalkboard and a sink supplied with hot and cold water.

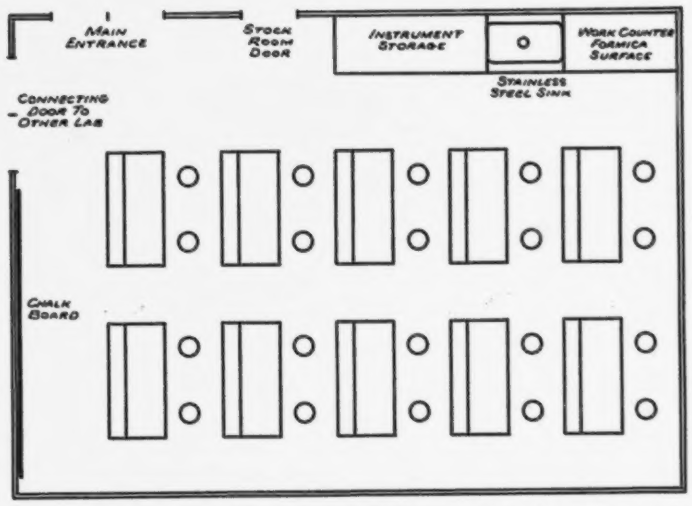
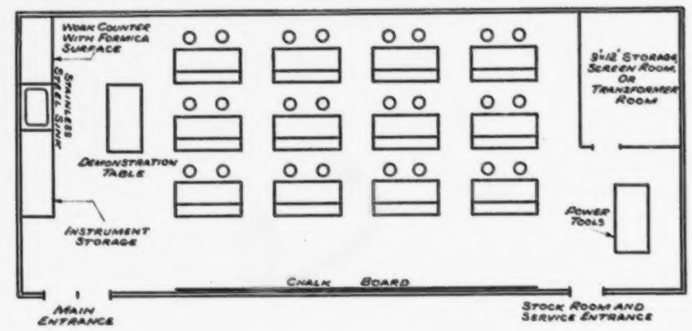

Main Entrance
Stock Room Door
Instrument Storage
Work Counter Formica Surface
Stainless Steel Sink
Connecting Door To Other Lab
Chalk Board

Figure 11.—An example of a small electronic laboratory layout using work benches for teams of two students each. Figure 12.—A laboratory for 24 electronic students showing 12 benches.


Work Counter With Formica Surface
Stainless Steel Sink
Demonstration Table
Instrument Storage
9' × 12' Storage Screen Room, Or Transformer Room
Power Tools
Chalk Board
Main Entrance
Stock Room and Service Entrance

Two examples of arrangements for individual work benches within an electronic laboratory are shown in figures 11 and 12. All wiring to the benches should be delivered through overhead drops such as shown in figure 13, or through subfloor channels and floor outlets. Subfloor wiring may provide a more attractive-appearing laboratory arrangement than does wiring from overhead ducts, but usually makes it less easy to change location of work stations or equipment. A separate circuit breaker should be used for each bench.

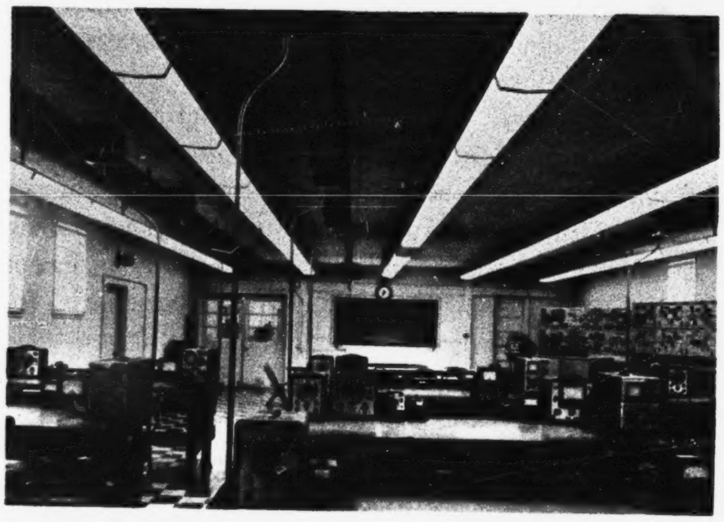
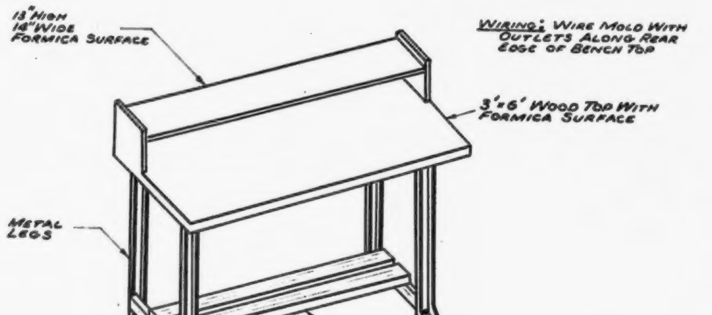


Figure 13.—Wiring to laboratory benches and equipment from overhead drops as shown here makes it easier to move benches and equipment to different arrangements than does wiring from subfloor channels and floor outlets.

Workbenches for the laboratories should be simple and functional. The steel leg, wooden top type shown in figure 14, has served satisfactorily. Electric wiring to supply power to this type of bench is conveniently arranged by attaching a wire mold plug strip along the rear edge of the bench top. The molding serves as a rear stop to prevent equipment from being pushed over the edge. Benches of this type are available commercially, or the legs may be purchased and the remainder fabricated by the purchaser. Figure 13 illustrates the use of this type of work bench in a laboratory. There are many different styles of work benches which would be equally satisfactory. Figure 15 is a sketch of one which provides additional storage space as well as a somewhat more attractive appearance.

Figure 14.—An example of an electronic labortory workbench.



Some laboratory benches are designed with a panel along the front of the riser which may contain various power outlets and controls as well as some permanently mounted measuring equipment. Such a panel arrangement has several advantages, including convenience and improved appearance. Permanent mounting of instruments, however, tends to limit the versatility with which the instruments may be used.

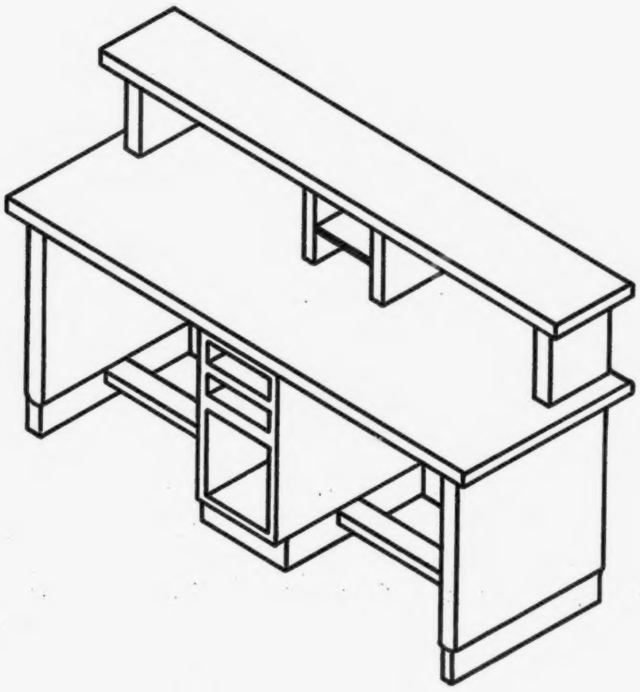


Figure 15.—Another example of an electronic laboratory workbench. This one is designed to provide storage space, a desirable feature.

Figure 16 shows a glass front cabinet which provides a convenient, necessary, and attractive place to store instruments within a laboratory, as illustrated in the background of figure 17. Closed storage is recommended because it keeps items clean, and may be locked to provide better control of the apparatus.

An important "nonteaching" function of the technical instructor is the preparation, development, and revision of laboratory exercises. It is

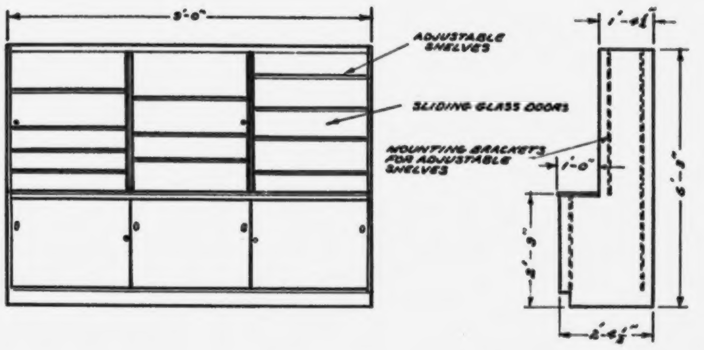


Figure 16.—Equipment storage cabinet. Figure 17.—The storage cabinets in the background are like the one illustrated in Figure 16. They have glass doors and provide safe, clean, closed storage.

therefore important to include space in the floor plan where the instructors can privately conduct laboratory work. Such a place, the instructor's laboratory, is included in both figures 9 and 10. This small laboratory should be located close to the offices of the instructors and also close to the laboratory equipment storage area. Equipment for this purpose must include high quality instruments for testing and demonstration work, as well as instruments typical of those used by the students. Sufficient work space should be available so instructors can leave experimental setups intact for whatever length of time is required to complete the developmental work—days or weeks, if necessary.

Office Space for Staff

Suggested office space for staff is indicated on both of the examples of schematic diagrams for an electronic department, figures 9 and 10. Office space should be provided for each instructor, and it is recommended that no more than two staff members be located in any office. More than two staff members occupying an office tends to discourage students from approaching instructors for assitance.

It is desirable to have a waiting room adjacent to staff offices where students can study comfortably while waiting for the instructor's assistance. The waiting room may house the departmental secretary who can arrange conference appointments for students if necessary. The conference room shown in figure 10 may also be used for student and staff conferences. No specialized equipment is needed for electronic department staff offices.

Equipping the Laboratories, and Their Cost

Equipping adequate laboratories for the teaching of electronic technicians is expensive. Experience shows that it is most desirable to start a program in fully equipped laboratories; but, if necessary, it is feasible to build laboratories, install work stations and provide the *minimum of laboratory equipment* required to begin the teaching program. This allows the program to be started with a minimum outlay of funds, and permits the cost of additional necessary or desirable equipment required for a well-equipped electronic teaching facility to be spread over a period of time.

Experience has shown that the department head or instructor should make final decisions on the choice of laboratory equipment because of his knowledge of technical details. The instructor can avoid costly mistakes which often result if non-technical personnel attempt to equip a scientific laboratory.

Surplus equipment, from either private or public organizations, can be an important source of good materials and hardware for equipping electronic laboratories. Government surplus property may often be an especially attractive source of either standard or specialized components, units, assemblies, mechanisms, instruments and systems, at a cost which usually is only a small fraction of their cost new. Educational institutions are high on the priority list of agencies to which government surplus property is made available.[1]

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[1] U.S. Department of Health, Education, and Welfare. Office of Field Administration. Division of Surplus Property Utilization.

Directory: Directors of State Agencies for Surplus Property and Regional Representatives, Division of Surplus Property Utilization, Department of Health, Education, and Welfare. 1965

How to Acquire Federal Surplus Personal Property for Health, Education, and Civil Defense Purposes and Federal Surplus Real Property for Health and Educational Purposes. 1965

Surplus Material and Science Education. 1964

Washington: U.S. Government Printing Office.

Distribution of surplus property within the States must be made through State agencies for surplus property. Most such State agencies maintain one or more distribution centers at which authorized representatives of eligible schools or school systems select materials for educational use. Usually one or more officials of a school or school system are designated as authorized representatives. Technical educators should communicate with their authorized school or school system representative, if one exists, to arrange to visit their State agency's distribution center, or write to the Director of their State agency for surplus property to obtain information regarding the procedures to be followed in acquiring equipment.

The State director of vocational and technical education in each State can provide specific information on the location of the government surplus property distributing agency in his State, and the persons in charge. Information on government surplus property may also be obtained by writing to:

Chief, Surplus Property Utilization Division
Department of Health, Education, and Welfare
Washington, D.C. 20201

Experience has shown that it is important to exercise the same elements of judgment and care in acquiring surplus equipment as is used in buying new equipment. Specific plans for the use, and sound justification for the need, should clearly be established for *any* surplus equipment; a careful analysis made of its total effectiveness in the program; its cost (including initial cost), transportation, space required, cost of installation, repair or tune-up (if incomplete), maintenance; and its pertinence in terms of obsolescence.

Only technically competent, responsible, and imaginative persons should select surplus equipment, and then, only after a thorough onsite inspection. This practice avoids the temptation or tendency to acquire attractive but obsolete, irrelevant, bulky, or excessive amounts of equipment.

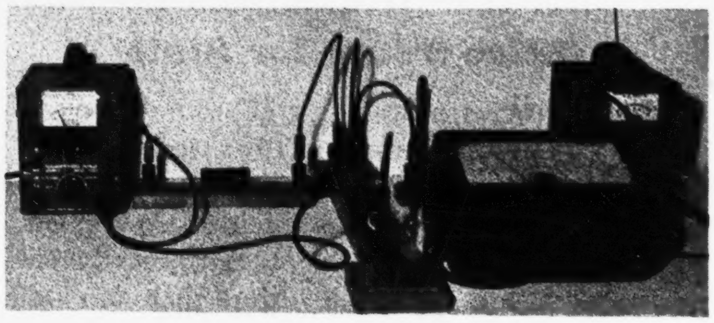
However, granted the foregoing approach, the resourceful department head or instructor can usually obtain quantities of components and materials (often by disassembling units or systems), meters, instruments, apparatus, and other essential up-to-date equipment for electronic laboratories at a very reasonable cost.

Simple, low-cost basic mechanisms (commercially made or prepared in the school laboratory) may sometimes be used instead of complete, self-contained assemblies or systems for teaching electronic principles and equipment. The extent of their use depends on the depth of the teacher's industrial experience and ingenuity, and must not exclude use of standard electronic apparatus. Experience has shown that maximum student contact with and reference to commercially available equipment in the laboratory will accelerate the student's use of acquired knowledge and skills in industry upon completion of the curriculum.

The quick-connect (snap on, clip on, plug in, or banana connections) wiring and simple components to build up various circuits and simple systems to illustrate many electronic principles have been found to be a very effective means of providing essential experience to students without the expenditure of valuable learning time.

Figure 18 illustrates how the rapid build-up and tear-down approach to electronic circuit systems may be used. Each of the components mounted on the wooden blocks shown in figure 18 is equipped with terminals for quick connection. Each of those shown in the illustration are one of a series representing a range of capacity. The ones suited to the particular circuit for the experiment illustrated in figure 18 were selected, quickly hooked up, the other essential elements (power supply, meters, etc.) connected; and the experiment performed with a minimum of assembly time and a maximum of use as a system for laboratory study. Tearing down (disassembling) is equally simple. The components and connecting wire elements can be returned to their respective series in storage, ready to be used for the next experiment requiring components of those particular characteristics. The various series of components can be mounted on blocks by school or student personnel, or can be brought to specification from contractors for a nominal cost.

Figure 18.—An application of rapid build-up-tear-down technique used in setting up electrical networks for laboratory experiments.



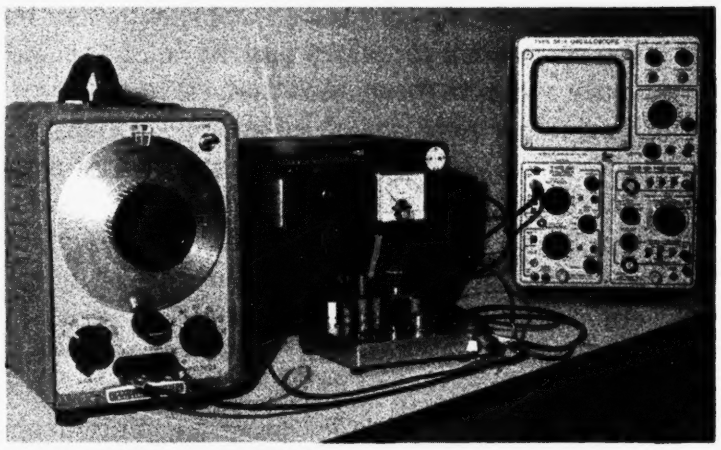


Figure 19.—This universal tube and transistor socket board with a single stage amplifier circuit fabricated on it permits use of rapid build-up-tear-down technique without damage to components.

The small assembly in the central foreground in Figure 19 is an example of a Universal Tube and Transistor Socket Board which was built as a project in the fourth semester Electronic Design and Fabrication course. It is a very flexible, highly useful, and efficient element in several laboratory experiments; and represents a more sophisticated use of the principle of quick-assembly than the single component elements shown in Figure 18 because it is itself an assembly capable of accommodating variability in the tubes and transistors used in it. The design and production of several of the universal units shown in Figure 19 provided the laboratory with a valuable and time-saving piece of apparatus and, at the same time, required the students who designed and made them to find the solutions to the complex design and fabrication problems of making a modern printed circuit device, described in the captions for Figures 20, 21, and 22.

Demonstrators and simulators for teaching various concepts, processes, principles, devices, and interrelations in systems are available for teaching electronics. In setting up an electronics program, however, the planners of the teaching program and laboratory equipment should make a thorough study of *all* the simulation, demonstration, and teaching systems available *at that time.*

There is an increasing number of manufacturers of these units. The pertinence, excellence, and effectiveness of their products provide a means of placing pre-assembled equipment systems in the electronics laboratory, usually designed specifically as a teaching unit, thus saving considerable time and effort for the instructor.

Examples of some types of demonstrators and simulators designed for teaching are:

1. Electrical phenomena demonstrator
2. Electronic teaching demonstration unit
3. Instrumentation electronic console demonstrator
4. An instrumentation function demonstrator
5. Industrial process dynamic demonstrator
6. Analog computer
7. Digital computer
8. Control system analog demonstrator
9. A tape controlled automatic process control demonstration unit

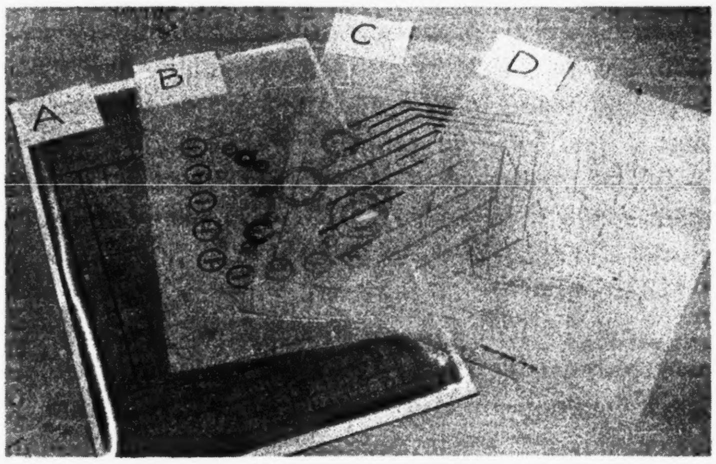


Figure 20.—Initial planning sequence for printed circuit universal tube and transistor socket board shown in Figure 19. The following steps are required in its design:

(A) Scale drawing of chassis with center locations of components shown. (B) First overlay showing parts to scale in final positon and orientation. This sketch includes mounting nuts of components. (C) Second overlay showing final sketch of proposed printed circuit board layout. (D) Third overlay showing necessary under-chassis wiring between components and printed circuit board.

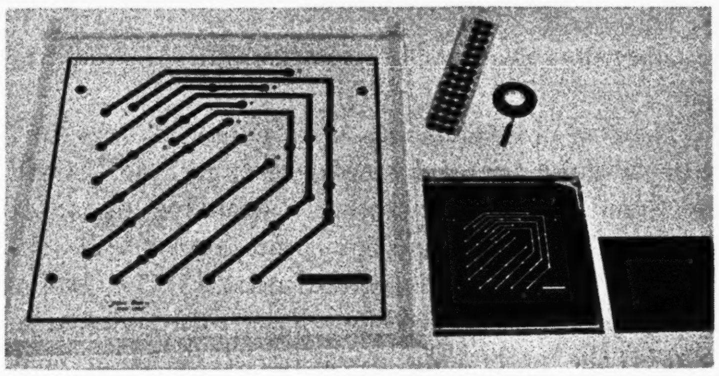
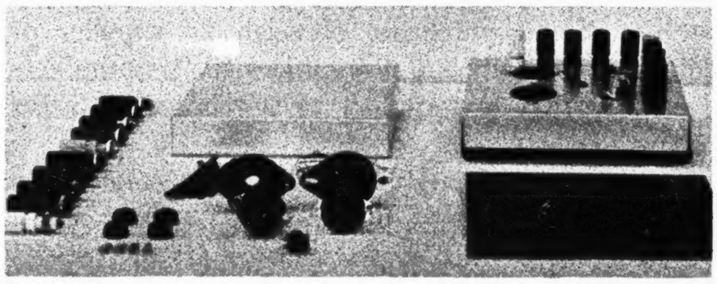


Figure 21.—After initial design steps, the work proceeds to this final tape drafted printed circuit board plan, photo reduced negative, and the etched printed circuit board.

Figure 22.—The chassis, components, and printed circuit board shown before and after fabrication.



Some of the foregoing demonstration and simulation equipment designed for teaching cost a few hundred dollars; others are complex demonstration units with wide applicability in teaching electronics, costing up to several thousand dollars.

Experience shows that when purchasing demonstration, simulation, or packaged systems of instructional equipment, the department head or instructor who is responsible for its use should satisfy himself that the equipment or system is completely operable and suitably serves the needs for which he is acquiring it by having it demonstrated in the manner in which he will be operating it. Further, an essential assurance of satisfaction to both the buyer and seller is the inclusion in the sales contract of a provision that a qualified representative of the selling agency install or demonstrate satisfactory operability after installation of complex or very expensive units or systems of laboratory equipment.

Suppliers of simulation and demonstration equipment may be found in scientific equipment suppliers' lists, purchasing directories (such as *Thomas' Register*), telephone directories, and in advertisements in education and trade journals. Experience shows that well-equipped electronic teaching laboratories include simulators or demonstrators for at least some of the systems or phenomena listed above. A budget for the purchase of such initial teaching equipment might well require from $10,000 to $14,000 in addition to the laboratory equipment specifically listed in this guide. The department head or instructor should select the specific demonstration or simulator units considered most suitable.

The cost of establishing, equipping, and operating a department for teaching electronic technicians will be found to vary somewhat, depending upon (1) whether its location is near or far from major suppliers, (2) the size of the department, (3) the quality of equipment or supplies purchased at a given time, and (4) the method of purchasing. If the equipment can be bought as a part of a large purchase of scientific equipment through a central purchasing agency, the total price of equipment and supplies may be somewhat less than if the items are purchased separately. Small purchases of scientific supplies or equipment usually are not subject to the supplier's discounts that are applied to purchases of larger quantities.

When plans to establish, enlarge, or re-equip an electronics department progress to the point which requires a detailed and precise estimate of costs, it is suggested that the services of major suppliers be obtained so the cost estimates may be complete and sufficiently accurate for current budgetary purposes. Prior to a major purchase of equipment, a thorough examination should be made of the potential suppliers by the department head or instructors, because in electronics as in other technologies, major changes are constantly taking place. The purchase of up-to-date equipment of good quality is the best preparation for a successful program for electronics technicians.

In initiating an electronics program, individuals planning the facilities and purchasing the electronics laboratory equipment should consider what, if any, equipment is already available at the institution. If some electrical and electronics equipment is a part of the facilities for physics courses, joint use of some of it may be feasible and prevent duplication of expensive equipment.

However, joint use of apparatus and equipment requires carefully coordinated planning with the other departments since it is essential that each department have sufficient equipment for its own needs *at the time* it is needed for each program.

Assumptions made in the estimated costs are for the cost of completely supplying and equipping an adequate electronic department for teaching 20 to 25 first year and 20 second year electronic student technicians at the date of this publication. They are based upon the acquisition of modern equipment and supplies of good quality, but not the most expensive.

The estimates do not include equipment or facilities for teaching special or auxiliary electronic courses for programs other than electronic technology.

The estimates assume the availability of a building of suitable construction equipped with normal services such as electricity, heat, and water but otherwise unfurnished. The cost estimates include piping, wiring, plumbing, and other distribution of services within each facility described.

No provision is made in this estimate for office furniture, conventional classroom blackboards, student seats, filing cabinets, and the conventional staff or instructor's office equipment. Classrooms, an adequately equipped physics department, and an equipped drafting room are assumed to be available, and their costs are *not* included here.

Neither the conventional firefighting equipment commonly used in school buildings nor special firefighting equipment required by local ordinances is listed here because the need for this should be specifically indicated for each locality.

The estimates are for well equipped laboratories having the furnishings described and listed hereunder and may be considered typical of those required for a good electronic technician educational program. Facilities for any given institution may be expected to vary in detail, but should include most of the facilities and equipment described to provide an adequately furnished and equipped department for teaching electronic technicians.

If possible, a completely equipped laboratory for a two-year program should be provided at the beginning of a new program. However, a minimum of laboratory equipment and apparatus required for starting the first year electronic classes may be acquired at the beginning of the program and additional instruments, items of equipment, and apparatus added as necessary and feasible. As a guide to the suggested minimum required laboratory equipment and apparatus for electronic teaching, the items marked with an asterisk (*) are considered to be items which are not needed at the beginning of the teaching programs but should be acquired as the programs progress. Where the number of items required is shown with an asterisk, for example, frequency meter *5(2), it means that 2 frequency meters should be acquired at the beginning of the teaching program and an additional 3 be added as needed or financially feasible.

The specifications for laboratory equipment listed in this section are typical for equipment to be used in teaching electronic technicians, and are offered as an assistance to the instructor or department head who may have the responsibility for purchasing the equipment. Quantities suggested are intended for a class of 20–25 students for optimum instructional conditions and will provide the necessary items for student instruction and practice.

When the program gets underway and all the recommended equipment has been purchased, it will still be necessary to have an annual equipment and supply budget. These funds are required to replace or repair equipment, restock expendable items, and purchase new equipment to meet regional modifications of the program. At least $3,000 to $5,000 per year should be planned to meet such needs, and substantially more may be required if special new types of equipment are developed and needed to keep the program up-to-date.

The equipment listed for the laboratories is divided into four major sections: (1) Equipment used primarily during the first year courses. (2) Equipment which is used in both the first and second year courses and thus necessary to operate the program the first year. (3) A list of supporting components, tools, and supplies required for the program, and necessary at the beginning of the first year. It is assumed that students will be expected to supply their own small hand tools because they will use them regularly in laboratory work throughout the entire program. If the students supply their own small tools, it reduces the storekeeping work of the electronic department and also reduces unaccounted-for losses of such items. (4) Equipment required for the second year.

The estimated total gross cost of additional items marked * which are needed to adequately equip the laboratories, but not absolutely essential at the beginning, are shown as a separate dollar figure for each laboratory.

Cost estimates for the various lists are given as a range of cost. Individual items are not priced for the reason that there may be substantial differences in the cost of comparable equipment and services in various locations.

Equipment Used Primarily in the First Year Laboratory

Quantity	*Description*
10	A. C. AMMETER Low range: 0-5ma Highest range: 0-1000ma
10	D. C. VOLTMETER Low resistance voltmeter, 0-25v. May be obtained by shunting a high resistance meter.
20	MULTIMETER D. C. voltage and current; AC voltage; ohms. D. C. at 20,000 ohms per volt, lowest ranges 250 mv. and 50 μa full scale.
10	WATTMETER 0-100 Watts; AC-DC dynamometer type movement
3	CAPACITY METER 10 pf to 100 mf.
5	DISTORTION METER Frequency range: audio Distortion ranges: 0-1% to 0-100%
10	MAGNETIC COMPASS
10	MICROMETER CALIPER

Estimated Total Cost: $3,000 to $3,500.

Equipment Used in Both the First and Second Year Laboratories

Quantity	Description
*20(10)	OSCILLOSCOPE Bandwidth; DC to 4 Mc/s Max. sweep speed 1 μs/cm Sensitivity: 50 mv/cm
20	VACUUM TUBE VOLTMETER AC volts; DC volts; Ohms
*20(10)	SIGNAL GENERATOR Audio and low RF
1	TUBE TESTER
3	GRID DIP METER 100 K c/s to 4.5 M c/s
1	TRANSISTOR CURVE TRACER
1	IMPEDANCE BRIDGE Frequency range: 20 c/s to 100 Kc/s. For measurement of L, C, Q of coils, D of capacitors
*20(10)	POWER SUPPLY 0-400 volts, 100 ma, regulated
*40(20)	POWER SUPPLY 0-30 volts, 250 ma
10	VARIAC 0-130—volts, 7.5 amps

Estimated cost for minimum requirement: $17,000 to $19,000.

*Additional for well-equipped laboratory—Estimated Cost: $12,000 to $14,500.

Supporting Components, Tools, and Supplies

Supporting Equipment Components

Quantity	Description
	ASSORTED CAPACITORS
10	CONDENSER DECADES
	ASSORTED RESISTORS
	ASSORTED POTENTIOMETERS
10	RHEOSTATS
10	RESISTOR DECADES
50	VACUUM TUBES
30	GAS TUBES
20	PHOTOTUBES
50	TRANSISTORS
20	PHOTOTRANSISTORS
20	LIGHT-SENSITIVE RESISTORS (CDS CELLS)
20	SEMICONDUCTOR DIODES
20	THERMISTORS
10	SILICON CONTROLLED RECTIFIERS
10	TRANSFORMERS AND CHOKES
10	AUDIO OUTPUT TRANSFORMERS
10	POWER TRANSFORMERS
10	CHOKES
10	CARBON FILIMENT LAMPS
20	BAR MAGNETS
10 lb.	IRON FILINGS
20	CHASSIS
10	I. F. AMPLIFIER 60 Mc/s; gain of about 50DB; bandwidth about 10 Mc/s

Estimated Total Cost: $3,000 to $3,500.

Supporting Equipment Tools

Quantity	Description
10	SOLDERING GUNS
5	SOLDERING IRONS 140 watt, 115 volts
10	SOLDERING IRONS Miniature, 6 volt, 12 watt, with transformer
3	ELECTRICIANS KNIFE
2	SHEET METAL BRAKE For small chassis construction
2	PORTABLE ELECTRIC DRILL
2	DRILL PRESS ½ inch chuck
2	LATHES (Small—½ inch stock capacity)
1	BENCH GRINDER Dual-arbor
1	MILLING MACHINE (Small)
4	BENCH VISE Fixed-base
3	SCREWDRIVERS, PLASTIC HANDLE Assorted sizes
2	SCREWDRIVERS, PLASTIC HANDLE Phillips
1	SET OF JEWELER'S SCREWDRIVERS
1	SET OF ALLEN HEX SCREWDRIVERS
4	LONG-NOSE PLIERS
4	DIAGONAL CUTTERS
4	UTILITY PLIERS
4	TWEEZERS
2	SET OF ALIGNMENT TOOLS
1	TAP AND DIE SET
1	HOLE PUNCH SET

Quantity	*Description*
2	NUT DRIVER SET
4	HACK SAW FRAME Adjustable, 12 inches
4	TIN SHEARS
4	WIRE STRIPPER
4	WIRE GUAGE
2	SET OF MINIATURE FILES
5	FILES, ASSORTED
4	HAMMER Ball peen
4	TORCH, PROPANE
10	WIRE BRUSH
20	MAGNIFYING GLASSES

Estimated Total Cost: $2,000 to $2,500.

Supporting Equipment Supplies

Quantity	*Description*
1000 Ft.	HOOK-UP WIRE (ASSORTED)
5 Lb.	SOLDER
15 Rolls	ELECTRICAL TAPE
1 Sheet	COPPER-CLAD
2 Gross	MACHINESCREWS(ASSORTED)
2 Gross	NUTS (ASSORTED)
10	HACK SAW BLADES, 12 INCHES
15	HIGH SPEED DRILLS
10	SOLDERING IRON TIPS
20	SOLDERING GUN TIPS
100 Sheets	SANDPAPER, (ASSORTED)
20 Sheets	EMERY CLOTH, FINE
500	QUICK CONNECT HOOK-UP TERMINALS and CONNECTIONS (ASSORTED)
	MISCELLANEOUS OTHER SUPPLIES AS NEEDED

Estimated Total Cost: $400 to $500.

Equipment Used in the Second Year Laboratory

Quantity	*Description*
*3 (1)	VACUUM TUBE VOLTMETER DC volts with 100 megohms input resistance; AC volts with 2 pf input capacity and response about 500 M c/s
*2 (1)	ELECTRONIC VOLTMETER High sensitivity DC voltage and current; high sensitivity AC voltage, with 2 pf input capacity and response to above 500 M c/s
*5 (2)	FREQUENCY METER Crystal calibrator 100 Kc/s to 1000 Mc/s
5	RF POWER METER 2 to 30 Mc/s 50 watts
10	R. F. POWER BRIDGE Capable of measuring power levels from about 1 mw to about 10.0 mw when used with the thermistor mount listed below
10	R. F. DUMMY LOAD 52 ohms
5	DUMMY ANTENNA To meet specification of 1948 IRE "Standards on Radio Receivers, Methods of testing Am Broadcast Receivers"
3	TEST LOOP To meet specification of 1948 IRE "Standards on Radio Receivers, Methods of testing Am Broadcast Receivers"
*5 (3)	SWEEP GENERATOR Television VHF channel coverage; television IF coverage; markers
*2 (1)	TEST OSCILLATOR 10 c/s to 10 Mc/s Distortion less than 5% with ouput meter and calibrated attenuator
*3 (1)	TEST OSCILLATOR 500 Kc/s to 50 Mc/s Distortion less than 5%
1	INDUSTRIAL COUNTER 4 places, neon indicators
*5 (1)	ANALOG COMPUTER 5 channels
1	DIGITAL DEMONSTRATOR For demonstrating basic logic functions
5	POTENTIOMETER, PRECISION 0-1.6 volts Max. error ±0.0005 volt.
5	GALVANOMETER Self-contained; sensitivity: 0.005 Ma/mm; period: 2.5 seconds
5	ADJUSTABLE D. C. RESISTOR 0 to 999.9 ohms 9 decade steps Max. error ± 0.1% or 0.01 ohm
5	SHUNT BOX Range: 0.075 to 15 amps Output 150 millivolts Max. error ± 0.02%
5	VOLT BOX Range: 15,150,300 volts Resistance; 750 ohms/volt Output 150 millivolts Max. error: ± 0.02%
5	STANDARD POTENTIAL CELL EMF—within 1.01884 to 1.01964 absolute volts at 20C Max. error: ± 0.01% of certified value
*5 (1)	KELVIN BRIDGE Range: 0.00001 to 0.1 ohm Max. error— ratio: ± 0.2% standard: ± 0.1 scale division

5	**TAPPING KEY** Single contact and short circuit key
5	**SLIDEWIRE** 42 ohms Max. error: ± 1 division
5	**RESISTOR** 1 ohm Max. error: ± 0.1%
*5 (1)	**GUARDED WHEATSTONE BRIDGE** Range: 0.01 ohm to 1,111 megohms Max. error: ± 0.05% 0.0001 ohm up to 100 megohms; ± 0.5% above 100 megohms
5	**RESISTANCE STANDARD** 10 ohm Max. error: ± 0.02% at 0.3 ampere; ± 0.005% at 0.1 ampere
1	**IMPEDANCE BRIDGE** Frequency range: 400 Kc/s to 60 Mc/s
1	**Q-METER** 50 Kc/s to 50 Mc/s
5	**SIGNAL GENERATOR** 100 Kc/s to 30 Mc/s Output meter and output attenuator
10	**SIGNAL GENERATOR** 100 Kc/s to 110 Mc/s; with internal amplitude modulation
1	**SIGNAL GENERATOR** Frequency modulated with output meter and calibrated output attenuator 25 Mc/s to 480 Mc/s
*10 (5)	**SIGNAL GENERATOR** Frequency: 90, 100 and 107 Mc/s; 10.7 Mc/s with sweep; 100 Kc/s band width markers.
*1 (0)	**SIGNAL GENERATOR** 5 Kc/s to 50 Mc/s; with amplitude modulation, output meter and calibrated output attenuator
2	**PULSE GENERATOR** Repetition rate 25 c/s to 500 Kc/s Pulse duration adjustable, 0.1 sec. to 1 sec. Rise time less than 30 ns.
3	**SQUARE WAVE GENERATOR** 25 c/s to 1 Mc/s Rise time less than 30 ns.
10	**SQUARE WAVE GENERATOR** Driven by separate sine wave generator
1	**SIGNAL GENERATOR** 250 Mc/s to 960 Mc/s
10	**FREQUENCY METER** Absorbtion type cavity with micrometer tuning from about 8KM c/s to 12.5 Kmc connections to RG-52/U wave-guide
10	**AFC UNIT** Discriminator type is suitable. 60 Mc/s, with about 10 Mc/s bandwidth
10	**VIDEO AMPLIFIER** Amplifier gain about 100; response relatively flat from about 20 c/s to about 1 Mc/s.
10	**KLYSTRON TUBE** Type 2K25 is satisfactory
10	**PARABOLIC ANTENNA** Circular, 60 cm. diameter; cutler feed using Rg-52/U waveguide.
20	**ANTENNA STANDS** Microphone stands modified to support horn and parabolic antennas
20	**WAVEGUIDE ATTENUATOR** Variable, calibrated from about 3DB to 50DB. Type RG-52/U with flanges.
20	**WAVEGUIDE ATTENUATOR** Variable, uncalibrated; 3 DB to 30 DB; RG-52/U; flange output; may be either flap type or vane type
10	**WAVEGUIDE ATTENUATOR** Fixed, 3 DB; type RG-52/U waveguide flanges
10	**WAVEGUIDE ATTENUATOR** Fixed, 6 DB; type RG-52/U waveguide with flanges
10	**TUBE MOUNT** For 2K25 Klystron; shielded mount preferred; output RG-52/U to flange
10	**SERIES TEE** E-plane Tee junction of RG-52/U with flanges at all ports
10	**SHUNT TEE** H-plane Tee junction of RG-52/U with flanges at all ports
10	**CRYSTAL MOUNT** Type IN23 crystal mounted in a section of RG-52/U with flanges at both ends. Crystal current connector of coaxial type
10	**SLIDE SCREW TUNER** Screw adjustable in location and penetration. Guide RG-52/U with flanges at both ends
10	**TERMINATION** For waveguide type RG-52/U flange input; power rating about 1 watt
10	**TRANSITION** RG-52/U with flange input to coaxial output
20	**HORN ANTENNAS** Pyramidal; gain about 10 DB; VSWR less than 1.1. Flange input to RG-52/U.
10	**DIRECTIONAL COUPLER** Side wall, two-hole type. Mainguide of RG-52/U with flanges. Auxiliary guide RG-52/U with coaxial output. Coupling factor about 20 DB.
20	**WAVEGUIDE STANDS** Base and waveguide clamp for RG-52/U. Should be adjustable height type.

10	SLOTTED LINE Slotted section of RG-52/U with flanges. Broadband probe with internal crystal detector. Usable slot length should be about 10 cm. Coaxial output from crystal.
10	VSWR METER Narrow band tunable type for direct measurements of VSWR from 1 to 4
10	THERMISTOR MOUNT RG-520 waveguide mount with flange input
10	KLYSTRON POWER SUPPLY Must supply 6.3 VAC at 0.44 amps, beam voltage 300 volts at 25 ma; repeller voltage adjustable to 400 volts. Must have provision for internal pulse modulation of Klystron.

Estimated Cost for minimum requirement: $34,600 to $37,000.

*Additional for well-equipped laboratory—Estimated Cost: $8,000 to $10,500.

Summary of Costs

The listed equipment is basic and does not include items for specialized programs. The cost estimates assume the purchase of new equipment of good quality in the quantities indicated. Especially advantageous buying, acquisition of suitable government or private surplus equipment, or unusually ingenious use of components built into teaching systems by the instructional staff may make it possible to equip electronic teaching laboratories for less cost; but for estimating the probable cost of equipping an electronic technology program these cost reduction potentials usually should *not be counted on.*

Therefore, the total cost of equipping for an electronic technology program, based on prices in 1965, may be estimated as follows:

Items	*Estimated Cost*
Work benches, fixtures, and storage cabinets, installed	$ 15,000 to $ 20,000
Suggested allowance for demonstration, simulation and special teaching equipment	10,000 to 14,000
Equipment used primarily in first year courses	3,000 to 3,500
Equipment used on both first year and second year courses	
Minimum required equipment	17,000 to 19,000
*Additional to fully equip laboratories	12,000 to 14,500
Supporting components, tools and supplies	
Components	3,000 to 3,500
Tools	2,000 to 2,500
Supplies	400 to 500
Equipment required for second year courses	
Minimum required equipment	34,000 to 37,000
*Additional to fully equip laboratories	8,000 to 10,500
Total estimated cost to fully equip the program	$105,000 to $125,000

The total estimated cost of $105,000 to $125,000 to fully equip an electronic technology program may, if necessary, be reduced to the total cost of the minimum recommended equipment by deferring the purchase of the items marked * (totalling $20,000 to $25,000) until their purchase is financially feasible. Thus the estimated cost of the minimum recommended equipment and facilities to undertake a program is from $85,000 to $100,000.

The foregoing estimates do not provide for the cost of the building, which, if constructed for the program, may be calculated at $12 to $14 per square foot of unfurnished laboratory space. Such space with special utilities and built-in furnishings, without portable equipment, may be estimated at $25 to $30 per square foot.

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Solid State Design. Horizon House, Inc., 610 Washington St., Dedham, Mass.

Solid State Electronics. Pergamon Press, 122 East 55th St., New York, N.Y. 10022

Trends in Engineering at the University of Washington. Engineering Experimental Station, University of Washington, Seattle 5, Wash.

Wireless World. Iliffe Electrical Publications, Ltd., Dorset House, Stamford St., London S.E. 1, Eng.

APPENDIXES

APPENDIX A

Selected List of Scientific or Technical Societies and Associations Concerned with Electrical and Electronic Engineering and Its Application

A list of some of the professional, scientific, and technical societies concerned with electrical and electronic engineering and its applications may be a useful source of instructional information and reference data.

The selected list which follows is not a complete listing of all such organizations; and inclusion does not imply special approval of an organization, nor does omission imply disapproval of an organization. Details regarding local chapters or sections of societies have been omitted.

It is suggested that teachers and others desiring information from the organizations listed below should address their inquiry to "The Executive Secretary" of the organization. A request for information about the organization and its services, or for specific information usually can be answered promptly by them.

The following societies are listed and briefly described:

Institute of Electrical and Electronics Engineers
American Institute of Aeronautics and Astronautics
American Institute of Physics
American Institute of Plant Engineers
American Nuclear Society
American Radio Relay League, Inc.
American Society for Engineering Education
American Society of Safety Engineers, Inc.
American Specification Institute
Armed Forces Communications and Electronics Association
Audio Engineering Society
Conference on Electrical Insulation
Illuminating Engineering Society
Instrument Society of America
National Association of Power Engineers, Inc.
Radio Technical Commission for Aeronautics
Society of Aerospace Material and Process Engineers
Society for Experimental Stress Analysis
Society for Nondestructive Testing, Inc.

INSTITUTE OF ELECTRICAL AND ELECTRONICS ENGINEERS, (IEEE), Box A, Lenox Hill Station, New York, N.Y. 10021.

History: Merged with Institute of Radio Engineers, Inc., as of January 1, 1963, to form the new society. 200 Sections.

Purpose: To serve engineers and scientists in electrical engineering, electronics, allied fields; membership includes 20,000 students. Holds numerous meetings and special technical conferences. Conducts lecture courses at the local level on topics of current engineering and scientific interest. Assists student groups. Awards medals, prizes, and scholarships for outstanding technical achievement.

Total Membership: 156,500

Publications: *Proceedings of the IEEE*, monthly; *IEEE Spectrum;* monthly; *IEEE Student Journal*, bi-monthly; *IEEE Directory*, biennial; *IEEE Transactions*, irregular.

AMERICAN INSTITUTE OF AERONAUTICS AND ASTRONAUTICS, 1290 Avenue of the Americas, New York, N.Y. 10019.

History: Founded in 1963 by merger of American Rocket Society and Institute of Aerospace Sciences, Inc.

Purpose: To provide interchange of technological information in aeronautics and astonautics through publications and technical meetings, in order to foster overall technical progress in the field and increase the professional competence of individual members.

Total membership: 36,000

Publications: *Astronautics & Aeronautics*, monthly; *AIAA Journal*, monthly; *AIAA Bulletin*, monthly; *Journal of Spacecraft and Rockets*, bi-monthly; *Journal of Aircraft*, bimonthly; *International Aerospace Abstracts*, semi-monthly.

AMERICAN INSTITUTE OF PHYSICS, 335 East 45th St., New York, N.Y. 10017.

History: Founded in 1931 by the following member societies: Acoustical Society of America, American Association of Physics Teachers, American Physical Society, Optical Society of America, and Society of Rheology, reorganized 1946 to provide membership for other organizations and for individuals.

Purpose: To promote the advancement and diffusion of knowledge of the science of physics and its applications to human welfare.

Total Membership: Over 20,000 (Five member societies, two associate member societies, 15 affiliated societies, 166 corporate associates and 235 student sections).

Publications: *Physical Review*, semi-monthly; *Reviews of Modern Physics*, quarterly; *Journal of the Optical Society of America*, monthly; *Journal of the Acoustical Society of America*, monthly; *American Journal of Physics*, nine times a year.

AMERICAN INSTITUTE OF PLANT ENGINEERS, 1056 Delta Avenue, Suite 11, Cincinnati, Ohio 45208.

History: Founded in 1915. The first national convention was held in Chicago in 1955 with 19 chapters represented. At the beginning of 1960, there were 53 chapters in the continental United States, Hawaii, and Canada. Local chapters—68.

Purpose: To advance the science of engineering, further the professional interest of plant engineers, encourage unified organizational activity, and cooperate throughout the world with compatable organizations having similar objectives.

Total Membership: 2,570

Publications: *AIPE Newsletter*, monthly.

AMERICAN NUCLEAR SOCIETY, 244 East Ogden Ave., Hinsdale, Illinois 60521

History: Founded in October 1954. Sections: 26 local, and 26 branches.

Purpose: The integration and advancement of nuclear science and technology.

Total Membership: 6,111

Publications: *Nuclear Science and Engineering*, monthly; *Transactions*, semi-annual; *Nuclear News*, monthly; *Nuclear Applications*, bi-monthly; *Proceedings of the Conference on Hot Laboratories and Equipment*, annual.

AMERICAN RADIO RELAY LEAGUE, INC., 225 Main Street, Newington, Connecticut 06111.

History: Organized in 1914; incorporated January 29, 1915.

Divisions: 16 geographic divisions in the United States and Canada.

Purpose: Promotion of interest in amateur radio communication and experimentation; relaying of messages by radio; advancement of the radio art.

Total Membership: 100,000

Publications: *QST*, monthly; *Radio Amateur's Handbook*, annual. (Numerous other publications devoted to amateur radio published irregularly).

AMERICAN SOCIETY FOR ENGINEERING EDUCATION, 1346 Connecticut Ave., N.W., Washington, D.C. 20036.

History: Organized in 1893 as the Society for the Promotion of Engineering Education; merged with the Engineering College Research Association June 1946 to form the present society.

Divisions: Aeronautical, Architectural, Chemical, Civil, Cooperative Engineering Education, Educational Research and Methods, Electrical, Engineering Economy, Engineering Graphics, Evening Engineering Education, Graduate Studies, Industrial Liberal Studies, Mathematics, Mechanical, Mechanics, Mineral, Nuclear, Physics, Relations with Industry, Technical Institute. The Technical Institute Council is made up of the administrators of institutions having one or more curricula in engineering technology accredited by the Engineers' Council for Professional Development.

Purpose: The advancement of education in all its functions which pertain to engineering and allied branches of science and technology, including the process of teaching and learning, research, and public relations.

Membership: Approximately 550 individuals (Technical Institute Division only) and about 300 institutions.

Publications: *Journal of Engineering Education*, monthly, October through June, with special July–August issue devoted to engineering technology education; *The Engineering Economist*, quarterly; *Journal of Engineering Graphics*, three times per year; *Chemical Engineering Education*, quarterly.

AMERICAN SOCIETY OF SAFETY ENGINEERS, INC., 5 North Wabash Avenue, Suite 1705, Chicago, Illinois 60602.

History: Organized in 1911; present name adopted in 1914. Organized into eight regions and 82 chapters in the United States and Canada. Nine standing committees, including General and Technical Publications, Cooperative with Engineering Societies and Colleges, Safety Standards, Research and Laws and Regulations.

Purpose: To promote the arts and sciences in the prevention of accidents and the conservation of life, health and property; to attain a high standard in safety engineering, and to encourage the development of safety engineering as a profession.

Total Membership: 7,021

Publication: *Journal of the American Society of Safety Engineers*, monthly.

AMERICAN SPECIFICATION INSTITUTE, 134 N. La Salle St., Chicago, Illinois 60602.

History: Organized on March 17, 1921.

Purpose: To increase and distribute the knowledge and to improve the method of writing specifications for architectural and engineering materials, equipment and structures.

Total Membership: Approximately 300.

Publications: *Bulletins*, Irregular.

ARMED FORCES COMMUNICATIONS AND ELECTRONICS ASSOCIATION, 1725 Eye Street, N.W., Washington, D.C. 20006.

History: Organized in May 1946 as the Army Signal Association; name changed to Armed Forces Communications Association in 1948 after unification of Armed Forces. At the request of the industrial members who felt that their scope of operations was larger than communications, the name was changed in 1955 to present title. Fourteen sections; 67 chapters both nationally and internationally.

Purpose: To maintain and improve the cooperation between the Armed Forces and industry in communications, and in the design, production, maintenance, and operation of communication, electronic, photographic equipment in time of peace or war, and to preserve and foster the spirit of fellowship among former, present, and future service and industrial personnel in the field.

Total Membership: 12,000

Publication: *Signal*, monthly.

AUDIO ENGINEERING SOCIETY, P.O. Box 383, Madison Square Station, New York, N.Y. 10010.

History: Organized in 1948. Sections: Central New York, Japan, Los Angeles, New York, Pittsburgh, San Francisco. Student Sections: Indiana Technical College, Rensselaer Polytechnic Institute, Southern University.

Purpose: To promote the advancement of the theory and practice of audio engineering and its closely related arts, and the dissemination of important information in this field.

Total Membership: 2,780

Publication: *Journal*, quarterly.

CONFERENCE ON ELECTRICAL INSULATION, National Academy of Sciences, National Research Council, 2101 Constitution Avenue, N.W., Washington, D.C. 20418.

History: Established within the Division of Engineering and Industrial Research, National Academy of Sciences-National Research Council, in 1920.

Purpose: To encourage and provide for the participation of workers from many diverse disciplines in a common effort directed toward the attainment of a better understanding of dielectric phenomena and electrical insulation behavior. It shall also provide a national forum and correlation service for research and development activities in the field of its competence and provide assistance to the National Academy of Sciences-National Research Council (NAS-NRC) upon request in the conduct of its advisory functions.

Total Membership: 400

Publications: *Digest of Literature on Dielectrics*, Annual Report.

ILLUMINATING ENGINEERING SOCIETY, United Engineering Center, 345 East 47th Street, New York, N.Y. 10017.

History: Organized in 1906; incorporated in New York. Twelve regions, with 106 sections and chapters in the United States and Canada.

Purpose: To promote the advancement of theory and practice of illuminating engineering and dissemination of related knowledge.

Total Membership: 10,600

Publications: *Illuminating Engineering*, monthly; *IES Lighting Handbook*, every five years.

INSTRUMENT SOCIETY OF AMERICA, 530 William Penn Place, Pittsburgh, Pennsylvania 15219.

History: Organized on August 7, 1939, as American Society of Instrument Engineers; re-organized November 1939 as American Society for Measurement and Control; incorporated and name changed to present title 1946. There are 120 geographic sections in the United States and Canada.

Purpose: To advance the arts and sciences connected with theory, design, manufacture, and use of instruments in the various sciences and technologies.

Total Membership: 15,900

Publications: *Journal*, monthly; *ISA Transactions*, quarterly; *Automation and Remote Control*, monthly; *Industrial Lab*, monthly; *Instruments and Experimental Techniques*, bimonthly; *Measurement Techniques*, monthly.

NATIONAL ASSOCIATION OF POWER ENGINEERS, INC., 176 West Adams Street, Suite 1411, Chicago, Illinois 60603.

History: Organized October 25, 1882, as National Association of Stationary Engineers; incorporated and present name adopted 1928. 182 chapters.

Purpose: To provide cooperative action on problems affecting power plant operators and executives; to broaden the engineer's ability and earning capacity by exchange of information and experience; to provide a systematic education and service program; to direct a systematic effort for enactment of engineers' license laws in all States; to promote development of a fraternal spirit.

Total Membership: 12,500

Publications: *National Engineer*, monthly.

RADIO TECHNICAL COMMISSION FOR AERONAUTICS, Suite 302, 2000 K Street, N.W., Washington, D.C. 20006.

History: Organized 1935; The commission comprises an Assembly which governs and directs its activities by establishing broad policies and operating procedure; and Executive Committee which meets monthly to manage the activities of the Commission; Special Committees appointed by the Executive Committee to perform the technical work; and a Secretariat. The special committees contain experts from government and industry who pool their knowledge and talents on a voluntary basis to arrive at solutions to specific problems. The commission is not an official agency of the United States Government.

Purpose: To advance the art and science of aeronautics through the investigation of all available or potential applications of the tele-communication art, their coordination with allied arts, and the adaptation thereof to aeronautics; to carry out this objective, the Commission coordinates between government and industry on matters referred to it for consideration, and conducts studies and publishes findings and recommendations.

Total Membership: 110 organizations.

Publications: Intermittent.

SOCIETY OF AEROSPACE MATERIAL AND PROCESS ENGINEERS, General Electric Co., LJED—Building 700, Cincinnati, Ohio 45215.

History: Organized in 1945 as the Society of Aircraft Materials and Process Engineers; name later changed to present title.

Purpose: To provide an opportunity for the discussion of subjects of common interest and importance to persons engaged in material and process engineering in the fields of airframe, missile, propulsion, and related industries, so that the members may execute their responsibilities more proficiently, may broaden their professional outlook, and may prepare for higher and more far-reaching responsibilities.

Total Membership: 700

Publications: *News Letter*, bimonthly.

SOCIETY FOR EXPERIMENTAL STRESS ANALYSIS, 21 Bridge Square, Westport, Connecticut 06882.

History: Organized 1943. Sixteen local sections.

Purpose: To promote and encourage knowledge pertaining to experimental stress analysis; to hold conferences, meetings, and symposia for the exchange of ideas and exhibition of equipment; and to publish and distribute papers or articles on stress analysis.

Total Membership: 2,249

Publications: *Proceedings*, biennial; *Experimental Mechanics*, monthly.

SOCIETY FOR NONDESTRUCTIVE TESTING, INC., 914 Chicago Ave., Evanston, Illinois 60202.

History: Organized October, 1941, and incorporated in Massachusetts as the American Industrial Radium and X-Ray Society; name later changed to present title.

Purpose: To promote the art and science of nondestructive testing and to assist industry in supplying better quality products at less cost through the efficient use of nondestructive testing; and to publish material for benefit for members of the society.

Total Membership: 4,500

Publications: *Materials Evaluation*, monthly.

APPENDIX B

Sample Instructional Materials

The items included in this appendix are intended to illustrate the types of instructional materials which are appropriate throughout the curriculum. The formal classwork is usually organized around textual material to facilitate the coordination of outside study. The laboratory work, by contrast, is almost entirely custom designed.

It should be emphasized that material of this nature requires careful preparation. Both time and facilities must be available for the faculty members to satisfactorily develop such instructional material.

One of the primary advantages of the full-time technical program lies in the coordination of classroom or theory study with laboratory study. In order to illustrate this coordination, a representative unit has been selected from a course (Control Circuits and Systems) and the following materials included:

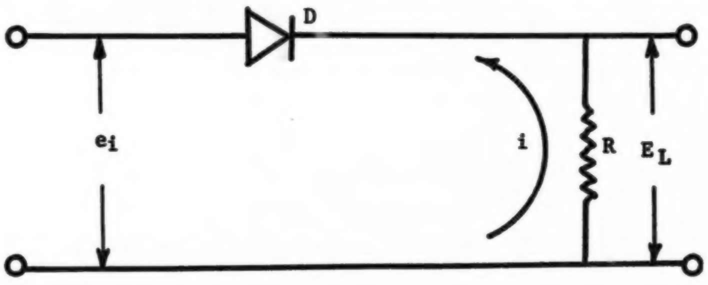
An outline of a unit of instruction
An outline of a typical lecture
A laboratory experiment
Sample laboratory reports (one informal, one formal)

UNIT OF INSTRUCTION: Halfwave rectifiers

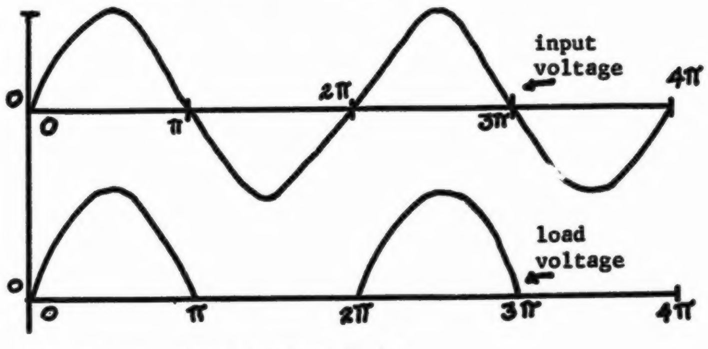
1. Voltage and current in a halfwave circuit
2. Rectification efficiency
3. Halfwave ripple factor

LECTURE OUTLINE: Voltage and current in a halfwave circuit

I. The Basic Halfwave Circuit



II. Waveshapes (Assuming a perfect diode)



III. Relationships (Perfect diode)

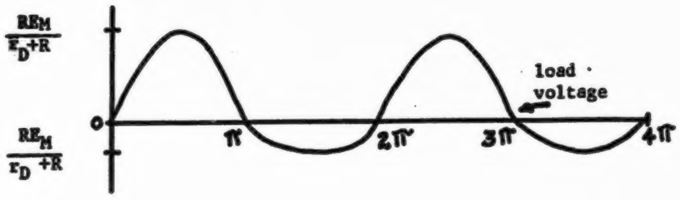
$$i = \frac{E_M}{r_D+R} \sin \omega t \quad \text{if} \quad 0 \leq \omega t \leq \pi$$

$$i = 0 \qquad\qquad \text{if} \quad \pi \leq \omega t \leq 2\pi$$

$$I_L = \frac{1}{2\pi} \int_0^{\pi} \frac{E_M}{r_D+R} \sin \omega t \, d\omega t$$

$$E_L = I_L R$$

IV. Waveshapes (Imperfect diode)



V. Relationships (Imperfect diode)

$$i = \frac{E_M}{r_D+R} \sin \omega t \quad \text{if} \quad 0 \leq \omega t \leq \pi$$

$$i = \frac{E_M}{r_R+R} \sin \omega t \quad \text{if} \quad \pi \leq \omega t \leq 2\pi$$

$$I_L = \frac{1}{2\pi} \int_0^{\pi} \frac{E_M}{r_D+R} \sin \omega t \, d\omega t - \frac{1}{2\pi} \int_{\pi}^{2\pi} \frac{E_M}{r_D+R} \sin \omega t \, d\omega t$$

$$E_L = I_L R$$

LABORATORY EXPERIMENT: Halfwave Rectifiers

Objective: Because of its simplicity and economy the halfwave rectifier is one of the most common rectifier circuits. In this experiment we shall examine the distribution of voltage and current within such a rectifier circuit.

Discussion: The halfwave rectifier is rarely used without a filter circuit. However, in this experiment we shall be primarily concerned with the action of the rectifier only; consequently, we shall consider it without a filter. Figure 23 shows a simple halfwave circuit.

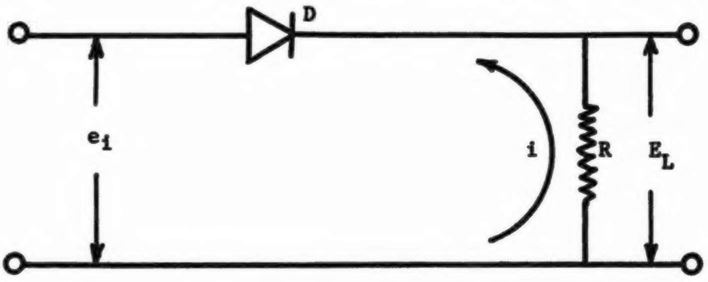


FIGURE 23. A simple halfwave rectifier circuit

The forward resistance of the diode will, of course, be nonlinear. However, the analysis of the circuit will be simplified if this quantity is assumed to have a fixed value (r_D). Such an assumption will introduce only a small error into our final results. Also, the diode may present a finite back resistance which would effect the final results. For the sake of simplicity we shall assume this effect to be negligible.

If a sinusoidal voltage is applied to the input, the circuit current will have a waveshape similar to that shown in Figure 24.

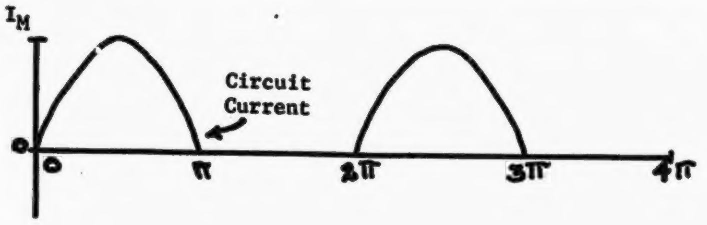


FIGURE 24. The circuit current

If we further specify the input voltage is to be given by the relationship

$$e_i = E_M \text{ Sin } \omega t$$

Then, considering the assumptions given above, we can write equations for the current,

$$i = I_M \text{ Sin } \omega t \quad \text{if} \quad 0 \leq \omega t \leq \pi$$
$$i = 0 \quad \text{if} \quad \pi \leq \omega t \leq 2\pi$$

Examination of the circuit reveals that the maximum current will be

$$I_M = \frac{E_M}{r_D + R} \tag{1}$$

consequently, we have

$$i = \frac{E_M}{r_D + R} \text{ Sin } \omega t \quad \text{if} \quad 0 \leq \omega t \leq \pi$$

and

$$i = 0 \quad \text{if} \quad \pi \leq \omega t \leq 2\pi$$

The DC current which will flow in the circuit will be the average of the current taken over the two intervals. That is,

$$I_L = \frac{1}{2\pi} \int_0^{2\pi} i \, d\omega t$$

However, since $i = 0$ in the interval $\pi \leq \omega t \leq 2\pi$ we have,

$$I_L = \frac{1}{2\pi} \int_0^{\pi} \frac{E_M}{r_D + R} \text{ Sin } \omega t \, d\omega t \tag{2}$$

Taking the integral renders

$$I_L = \frac{1}{2\pi} \left[\frac{E_M}{r_D + R} \text{ Cos } \omega t \right]_0^{\pi}$$

And evaluating the equation at the indicated limits we have,

$$I_L = \frac{E_M}{\pi(r_D + R)} \tag{3}$$

Finally, we know that

$$E_L = I_L R$$

Consequently

$$E_L = \frac{E_M R}{\pi(r_D + R)} \tag{4}$$

Which is, of course, the DC voltage across the load.

Materials:

1 Silicon diode
1 110 volt, 60 cycle source
1 oscilloscope
1 vacuum tube voltmeter
1 5K, 1w load resistor

Procedure:

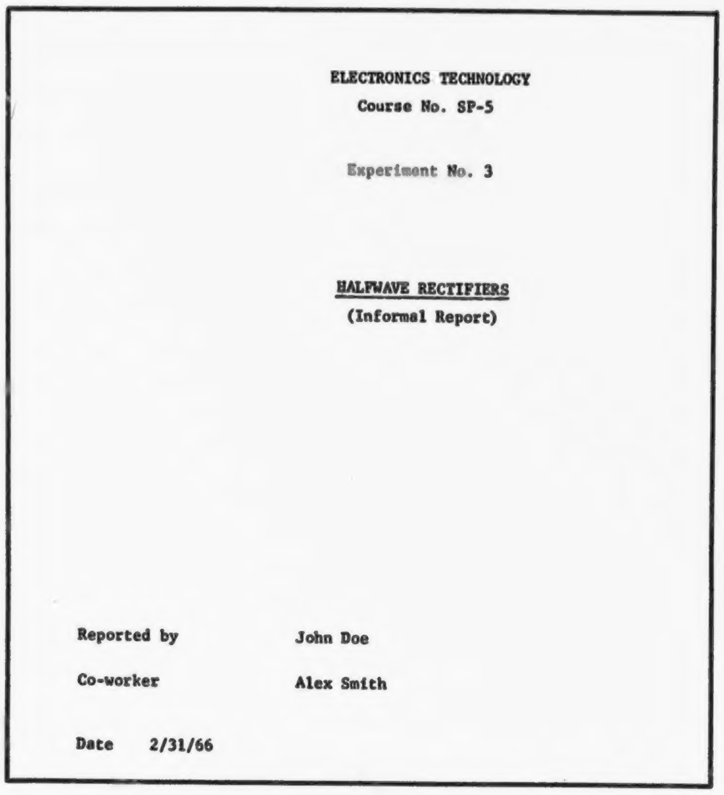
1. Construct the circuit shown in Figure 23.
2. Measure and record the peak value of the input voltage (E_m).
3. Measure and record the peak value of the voltage across the $5K$ resistos (E_{pk}).
4. Using the data from steps 2 and 3, compute the approximate value or r_D.
5. Measure and record the DC voltage across the $5K$ load resistor.
6. Using the data from steps 2, 3, and 4 and equation (4) from the discussion, compute the value of the DC voltage which should appear across the $5K$ resistor.
7. Compute the percent difference between the two values of DC voltage from steps 5 and 6.
8. View and record as accurately as possible the waveshape of:
   (a) The input voltage
   (b) the voltage across the diode
   (c) the voltage across the $5K$ resistor.
9. Using the value measured in step 5, compute the value of I_L.
10. Using the data from steps 2, 3, and 4 and equation (3) from the discussion, compute the value of I_L.
11. Compute the percent difference between the two values of I_L arrived at in steps 9 and 10.

Analysis Guide:

In the analysis of these data you should discuss the reasons for the differences between the values of voltages and currents that were encountered in the experiment. In particular you should discuss the factors to which these differences could be attributed.

Sample Reports:

The following reports are included to indicate the type of laboratory reports which are appropriate for use in the courses contained herein. The first report is of the informal type and would normally take the student about two hours to prepare after all of the data has been collected. The second report is of the formal type. Its preparation will normally take six to eight student hours exclusive of the time required to collect data.



ELECTRONICS TECHNOLOGY
Course No. SP-5

Experiment No. 3

HALFWAVE RECTIFIERS
(Informal Report)

Reported by John Doe

Co-worker Alex Smith

Date 2/31/66

FIGURE 25

Procedure:

1. The circuit in Figure 26 was constructed.
2. Various waveforms and voltages were recorded.
3. The measurements were compared to calculated values.

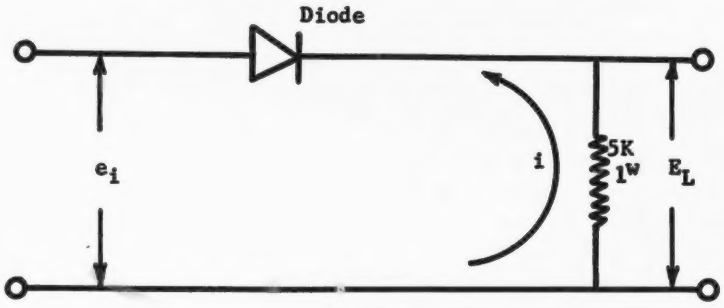
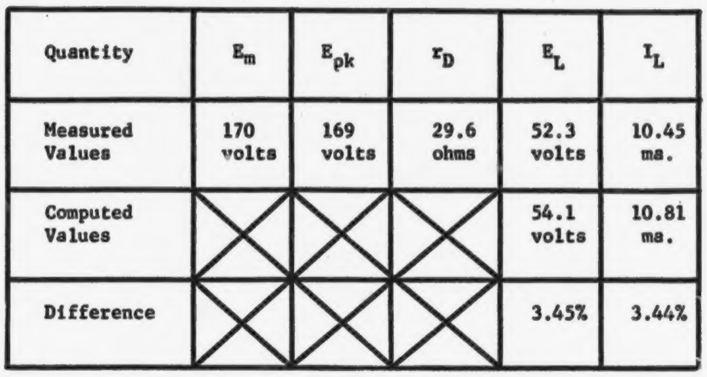


FIGURE 26. The experimental circuit

Equipment:

1 Silicon diode General Electric type 1N1692
1 Resistance decade Industrial Instruments Model DR-50 No. 8305
1 Vacuum Tube Voltmeter Radio Corp. of America Model WV-77E No. 40378
1 Oscilloscope Tektronix Type 535 No. 9463

Data:



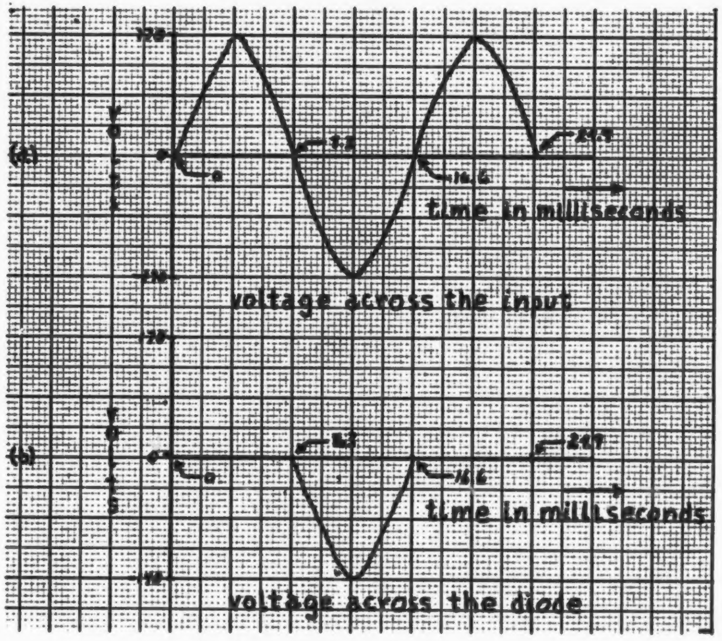
Quantity	E_m	E_{pk}	r_D	E_L	I_L
Measured Values	170 volts	169 volts	29.6 ohms	52.3 volts	10.45 ma.
Computed Values	☒	☒	☒	54.1 volts	10.81 ma.
Difference	☒	☒	☒	3.45%	3.44%

FIGURE 27. Data table

Curves: See attached graph sheet.

Analysis of Results:

The values measured in this experiment agreed very well with those predicted by the equations given in the discussion, the difference between the two being about 3.5%. The causes of this difference are not obvious, but could have arisen from any combination of several sources. For example, the voltage measurements used to compute the diode's forward resistance were taken with the oscilloscope and were within 1% of each other. A very small error in measuring either of these voltages would introduce a large error into the value computed for r_D. Fortunately, however, because of the great difference in value between r_D and the 5K load, even large errors in the value of r_D would introduce only small errors in the values of E_L and I_L. The instruments used to make the measurements should have been accurate to within about 5% of the indicated values. Since the differences between computed and measured values were less than 5%, it seems reasonable to conclude that the errors could be attributed almost entirely to the instruments.



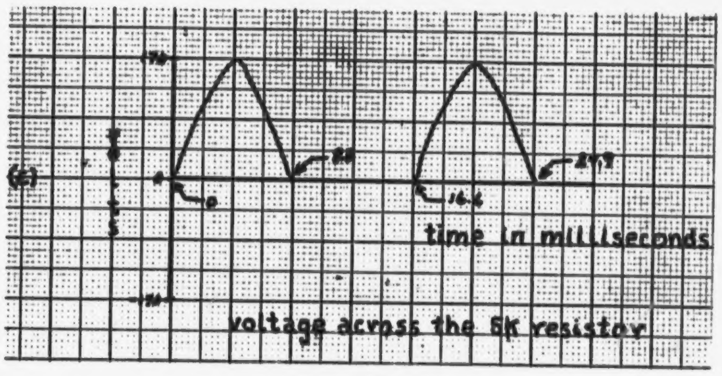
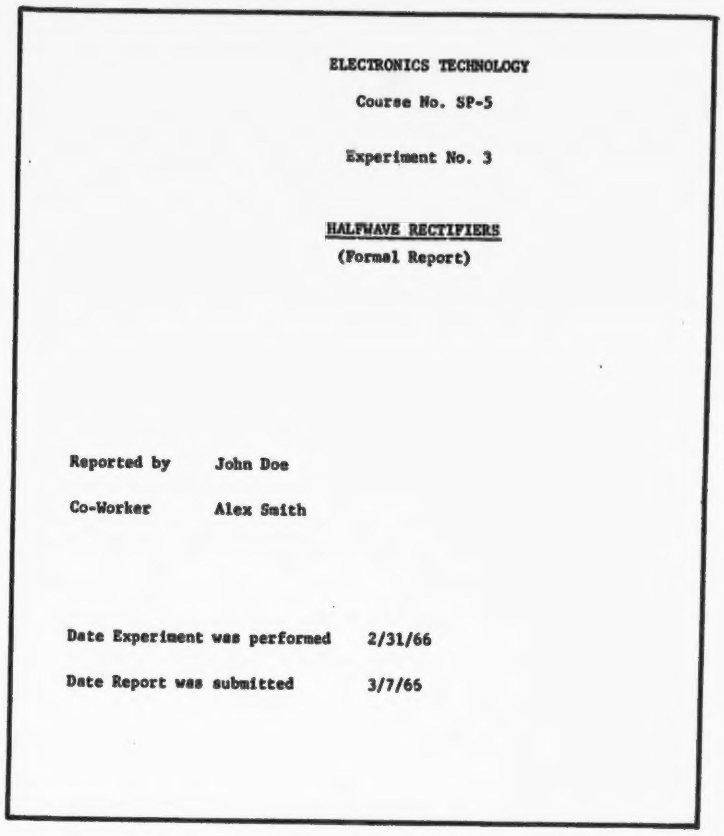


FIGURE 28

The waveshapes that were recorded indicate that the circuit was operating satisfactorily and that the assumptions made in the discussion were valid as far as this experiment was concerned.



ELECTRONICS TECHNOLOGY

Course No. SP-5

Experiment No. 3

HALFWAVE RECTIFIERS

(Formal Report)

Reported by John Doe

Co-Worker Alex Smith

Date Experiment was performed 2/31/66

Date Report was submitted 3/7/65

FIGURE 29

INTRODUCTION

In this experiment the operation of a simple halfwave rectifier was examined. The extent to which its performance could be predicted by a mathematical model was also investigated. The techniques employed in this experiment would be valid for any simple halfwave rectifier in which no filter was employed; provided that the forward resistance of the diode was small compared to the load resistance, and that the reverse resistance of the diode was large compared to the load resistance. Normally this would include most vacuum, gaseous, and solid-state diodes.

METHOD OF INVESTIGATION

A. Procedure

1. The circuit shown in Figure 30 was constructed.
2. Using an oscilloscope, the peak voltage at the input and across the 5*K* load resistor was recorded.
3. Using circuit values and the voltages measured above, the value of the diode's forward resistance (r_D) was approximated.
4. Using a V.T.V.M., the DC voltage across the 5*K* load was recorded.
5. The load current was determined from the data taken above.
6. Waveshapes at various points in the circuit were viewed and sketched.
7. The values of DC load voltage and current were computed using a mathematical model.
8. The measured and computed values of load voltage and current were compared.

B. Circuit Diagram

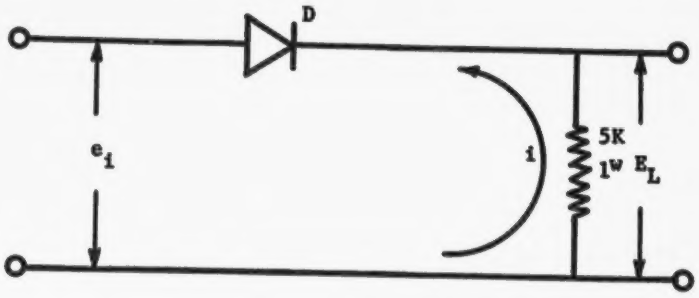


FIGURE 30. The experimental circuit

RESULTS

A. Data

1. Nameplate data of equipment

1 Silicon diode	General Electric Type 1N1692
1 Resistance decade	Industrial Instruments Model DR–50 No. 8305
1 V.T.V.M.	Radio Corp. of America Model WV-77E No. 40378
1 Oscilloscope	Tektronix Type 535 No. 9463

2. Observed and calculated data

Quantity	E_m	E_{pk}	r_D	E_L	I_L
Measured Values	170 Volts	169 Volts	29.6 Ohms	52.3 Volts	10.45 ma.
Computed Values	☒	☒	☒	54.1 Volts	10.81 ma.
Difference	☒	☒	☒	3.45%	3.44%

FIGURE 31. Data table

B. Sample Calculations

1. Diode resistance

$$\frac{r_D}{E_M - E_{pk}} = \frac{R}{E_{pk}}$$

$$\frac{r_D}{170\text{–}169} = \frac{5000}{169}$$

$$r_D = 29.6 \text{ ohms (by sliderule)}$$

2. DC voltage across the load

$$E_L = \frac{(E_M)(R)}{\pi(r_D + R)}$$

$$E_L = \frac{(170)(5000)}{3.14\ (29.6 + 5000)}$$

$$E_L = 54.1 \text{ volts (by sliderule)}$$

3. Percent difference between two values of DC voltage

$$\%\ \text{Diff} = \frac{E_L\ (\text{comp}) - E_L\ (\text{meas}) \times 100}{E_L\ (\text{meas})}$$

$$\%\ \text{Diff} = \frac{54.1 - 52.3 \times 100}{52.3}$$

$$\%\ \text{Diff} = 3.45 \text{ (by sliderule)}$$

4. DC current

$$I_L = \frac{E_L}{R}$$

$$I_L = \frac{52.3}{5000}$$

$$I_L = 10.45 \text{ ma (by sliderule)}$$

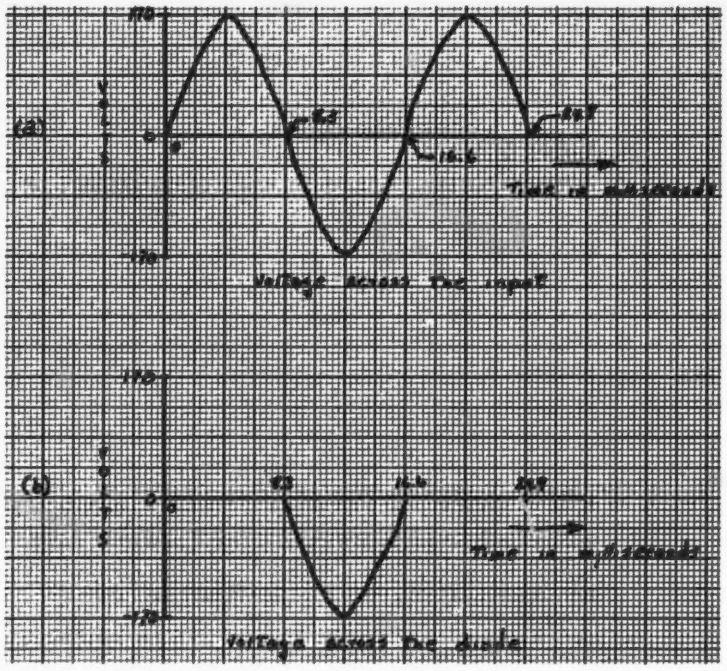
5. DC current

$$I_L = \frac{E_M}{\pi(r_D + R)}$$

$$I_L = \frac{170}{3.14\ (29.6 + 5000)}$$

$$I_L = 10.81 \text{ ma (by sliderule)}$$

C. Curves: See Figure 32.



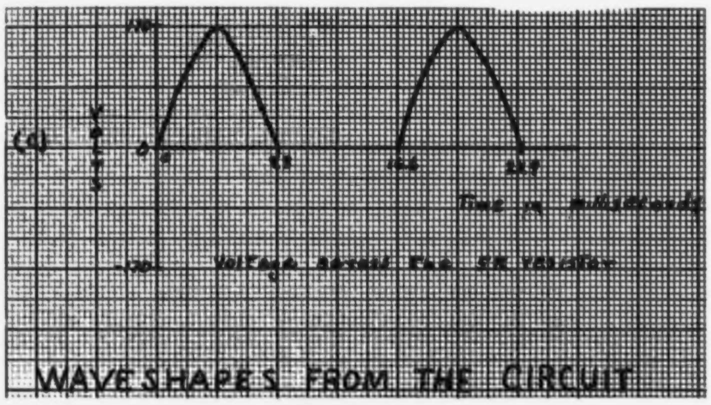


FIGURE 32.

ANALYSIS OF RESULTS

The circuit shown in Figure 30 is a simple halfwave rectifier. The waveform shown in Figure 32a was applied to the input terminals of the circuit. The input waveform appeared to be sinusoidal and had a peak value of about 170 volts. The period of the input waveform was approximately 16.6 milliseconds. These values were obtained by viewing the waveform with an oscilloscope. Presuming that they are reliable, they suggest that the frequency of the input was:

$$f = \frac{1}{T} = \frac{1}{0.0166} = 60 \text{ cps}$$

Consequently, the angular velocity would be

$$\omega = 2\pi f = 6.28 \times 60 = 377$$

As a result, if the waveshape were sinusoidal, it could be represented by the equation

$$e_i = E_M \text{ Sin } \omega t$$

Where $E_M = 170$ volts and $\omega = 377$ in the experimental circuit.

The forward resistance of the diode was almost surely nonlinear. However, to simplify the analysis it was assumed to be linear. This assumption is valid only if the forward resistance is a small enough portion of total circuit resistance so that its effect is also small. To insure that this condition did indeed exist in the experimental circuit, the waveshape of the voltage across the load was also viewed. This waveform is shown in Figure 32c. The peak value of this voltage was found to be approximately 169 volts. The voltage drop across the forward diode resistance (r_D) will be the difference between the peak input voltage (170 volts) and the peak load voltage (169 volts). Or in other words the voltage across r_D was about 1 volt. The approximate value of r_D would then be

$$\frac{1}{r_D} = \frac{169}{5000} \text{ or } r_D = 29.6 \text{ ohms}$$

This value was considered sufficiently small when compared to the load resistance to justify the assumption of linearity.

Figure 32c also provides some evidence that the reverse resistance of the diode is very much larger than the load resistance. If this were not the case, then the voltage in the interval between 8.3 ms and 16.6 ms in Figure 32c would not have been so nearly zero. Consequently, it shall be assumed that *no* current flows in the circuit when the input polarity is such as to require reverse flow through the diode.

The waveform of the voltage across the diode was also viewed and it indicated that the results suggested above were valid. This waveform is shown in Figure 32b. This waveform also helps to establish the validity of the other two, since it is known from Kirchoff's law that the input voltage must equal the sum of the voltage drops within the circuit. Visual inspection of Figure 32 reveals that the graphic sum of Figures 32b and 32c will at least approximate the input voltage waveform, 32a.

Under the presumption that the input voltage may be represented by

$$e_i = E_M \operatorname{Sin} \omega t$$

it becomes possible to represent the circuit current by the equations

$$i = \frac{E_M}{r_D+R} \operatorname{Sin} \omega t \quad \text{if} \quad 0 \leq \omega t \leq \pi$$

and

$$i = 0 \qquad\qquad \text{if} \quad \pi \leq \omega t \leq 2\pi$$

This conclusion is strengthened by the results presented in Figure 32c.

The DC current that will flow through the load will be the average current taken over the interval $0 \leq \omega t \leq 2\pi$. Or in other words,

$$I_L = \frac{1}{2\pi}\int_0^{2\pi} i \, d\omega t = \frac{1}{2\pi}\int_0^{\pi} \frac{E_M}{r_D+R} \operatorname{Sin} \omega t \, d\omega t$$

which reduces to

$$I_L = \frac{E_M}{\pi(r_D+R)}$$

The value which resulted from this equation differed from the value measured in the experiment by 3.44%. This difference could have arisen from any of several sources, some of which will be discussed later in this analysis.

Having the equation for the DC current it is possible to arrive at the following equation for the DC load voltage using ohms law.

$$E_L = (I_L)\,(R) = \frac{(E_M)\,(R)}{\pi(r_D+R)}$$

And again this value agreed with the measured data to within 3.5%.

The causes underlying the differences between the computed and measured quantities in this experiment could be divided into two categories:

1. Inadequacies on the part of the analysis presented above.
2. Difficulties rising out of the choice and use of the instruments.

The analysis presented may have been in error in that the input waveform may not have been *exactly* sinusoidal. Also, the assumption of linearity on the part of the forward diode resistance almost certainly introduced a small amount of discrepancy. The effect of nonlinearity would have been the alteration of the current waveshape so that it would not have been *exactly* sinusoidal even if the input voltage were. Assuming the reverse current to be nonexistant also introduced some error. It is felt, however, that errors of this type were probably extremely small compared to errors of the second type.

There are several ways in which the instruments used in the experiment could have affected the results. To start with, the oscilloscope was used to measure the peak voltages which were in turn used to determine the value of r_D, as well as in the equations for E_L and I_L. The accuracy of these measurements was probably no greater than ±5%. Also, since the value of r_D depended upon the difference between two virtually equal quantities, a small error in one of these measurements would have had a large affect on the value of r_D. For example, if the peak voltage across the load had been 168 volts instead of 169 volts (a difference of only about 0.6%) the resulting value of r_D would have been 59.6 ohms (a difference of about 100% over the previous value). As dramatic as this variation is, its effect on the final results would not have been great, since even if r_D were 59.6 ohms it still contributes only about 1% of the total circuit resistance.

Connecting either the oscilloscope or the VTVM across the load of course causes some "loading" effect. However, since both of the instruments had input resistances on the order of 10 megohms this effect could not have been great.

Perhaps the greatest source of error in the experiment arose from the accuracy of the instruments. The oscilloscope, VTVM, and resistance decade were all of about 5% accuracy and in some cases the instrument errors would have been additive. For example, if both the VTVM and the resistance decade contributed a 5% error in the same direction, the values of E_L and I_L could have been altered by a considerable amount. To illustrate this effect, suppose that the VTVM read 50 volts while the true value was 47.5 volts (meter reads 5% high) and the $5K$ resistor was actually 5250 ohms (5% too large) then the current would *seem* to be

$$I_L = \frac{E_L}{R} = \frac{50}{5000} = 10 \text{ ma}$$

while it was actually

$$I_L = \frac{E_L}{R} = \frac{47.5}{5250} = 9.05 \text{ ma}$$

The total error in this case being close to 10%. If any reading error were added to this value the total error would be correspondingly higher.

As a result it would seem that the actual differences encountered in the experiment are well within the limits established by the quality of the instruments, and are thus considered to be acceptable.

In conclusion, it can be said that the circuit encountered in this experiment performs effectively as a simple halfwave rectifier, and that the analysis technique employed is effective in predicting the DC load voltage and current in such a circuit.

APPENDIX C

Suggested Standards for Laboratory Report Writing

GENERAL CHARACTERISTICS

Tests of equipment are usually summarized in the form of a report. In most cases, the report is submitted to those who have not been actively engaged in the tests; hence, the report must be clear and concise enough to leave no doubt concerning the method of test and the interpretation of the results.

The report should be written in the past tense and in the third person. It should be impersonal throughout, personal pronouns being avoided. The report must be complete in itself so that it can be followed by a reader without extensive knowledge of the test under consideration. A good report is thorough, orderly, neat, and grammatically correct.

SPECIFICATIONS

1. Write with ink or use a typewriter.
2. Use 8½ x 11 inch paper. (Ruled paper for handwriting.)
3. Write on one side of the paper only.
4. Draw all illustrations, circuit diagrams, and curves neatly and carefully.
5. Letter or type all information on drawings, circuit diagrams, and curves. Do not mix lettering styles.
6. Assemble the sheets in the order given in the following report outline. Submit the material in a standard report folder with the brads inserted through the back cover only, with the heads on the outside.

REPORT OUTLINE

The material should be arranged in the following order:

I. Title page
II. Introduction
III. Method of Investigation
  A. Procedure
  B. Circuit diagrams
IV. Results
  A. Data
    1. Nameplate data of equipment
    2. Observed and calculated data
  B. Sample calculations
  C. Curves
V. Analysis of Results
VI. Questions

(Not more than one of the above six divisions should be included on a single page. Omit Roman numerals.)

DISCUSSION OF REPORT OUTLINE

I. Title Page
On this page should appear the name of the school, the course number and title, the date performed, the date submitted, the name of the student reporting, and the name of co-worker or co-workers. This page may be omitted if the form printed on the report folder includes these items.

II. Introduction
The introduction should be a concise statement setting forth the aim and scope of the investigation.

III. Method of Investigation

A. Procedure. In this section a general description of the procedure should be given. It should be comprehensive but brief. The enumeration and detailed description of routine mechanical operations and their sequence—such as closing switches, reading instruments, turning knobs, and so forth—should, in general, be avoided. However, when a specific method of mechanical operation is necessary to assure the validity or accuracy of the test data, it is important that the essential details be included in the description.

B. Circuit Diagrams. Each diagram should have a figure number, and should be referred to in the text material by that number. Each figure should have a descriptive title. Small diagrams may be included in the body of the description, or several may be drawn on one separate sheet if the result is not crowded. Standard symbols should be used.

IV. Results

A. Data. The first item under results should be the nameplate data—or equivalent identification—of the apparatus tested.
The original observed data and the calculated data should be presented in tabular form. If the observed data require corrections, these should be made before tabulation. Instrument identification numbers and ranges need not be copied from the original laboratory data sheet.

B. Sample Calculations. This section should consist of a sample of a complete calculation of each type involved in the determination of calculated data and the solution of problems. When a succession of calculations is required in order to reach a final result, the same set of observed data should be used in carrying through the successive sample calculations; i.e., the same sample figures that are selected from a data column should be used in all calculations involving that set of data.

C. Curves. All curve sheets should conform to the following specifications:

1. Use "twenty to the inch" coordinate paper, 8½ x 11 inches, for rectangular plots.
2. Plot in the first quadrant where only one quadrant is needed.
3. In general, make the axes intersect within the sectioned part of the paper. Leave the curve sheet margins blank.
4. Plot the independent variable as abscissa and the dependent variable as ordinate.

5. In general, start the scale of the dependent variable, but not necessarily the scale of the independent variable, at zero.
6. Choose scales that are easy to use and that do not allow points to be plotted to a greater accuracy than that justified by the accuracy of the data.
7. Indicate points plotted from data by visible dots or very small circles
8. Draw a smooth average curve through the plotted points except in cases in which discontinuities are known to exist. Use a French curve in drawing the curves.
9. Place a title containing all pertinent information on each curve sheet. The title should be lettered or typed. Label the axes and show the units in which they are marked.
10. Draw only related curves on the same sheet.
11. Insert curve sheets in the report so that they can be read from the bottom or right side.
12. Use ink for everything on the sheet except the curves themselves; these should be drawn with a colored pencil.

V. Analysis of results

The analysis of results is the most important section of the report. As the name implies, it should be a complete discussion of the results obtained. Part of the discussion should deal with the accuracy or reliability of the results. It is suggested, where applicable, that this section consist of a careful treatment of the effect on the results of the following:

(1) Errors resulting from the necessity of neglecting certain factors because of physical limitations in the performance of the test, (2) errors in manipulation, (3) errors in observation, and (4) errors in instruments.

A very important part of the discussion should be a comparison of the results obtained with those which would reasonably have been expected from a consideration of the theory involved in the problem. Whenever the theory is apparently contradicted, the probable reasons should be discussed.

When results are given in graphical forms as curves, the shape of each curve should be carefully explained. Such an explanation should state the causes for the particular shape the curve may have.

Any original conclusions drawn as a consequence of the laboratory procedure and a study of the results obtained should be included in this section.

VI. Questions

In this section should be included answers to any questions which are given as a part of the test.

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